Fundamentals of Photograph Conservation:

A Study Guide

NATIONAL ARCHIVES OF CANADA

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by

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Lugus

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Cover: A set of black-and-white photographic print samples used for testing image stability.
Courtesy of Dr. Edith Weyde, 1938. Effect of chemical restoration on a faded print showing treated image at bottom right.

Contents

Foreword

The purpose of the present study guide is to summarize laboratory experiments and their theoretical foundations that are helpful in introducing interested students to practical work in the field of photograph conservation. The book reflects the combined experience of several individuals who have worked in the area of fine art and photograph conservation at the National Archives of Canada. I should like to express my thanks to all of them who in the past have contributed their ideas and their skills to our efforts towards a better understanding of the nature of a photograph.

Struggling a few years ago to learn the techniques of preparing cross-sections of photographic materials for examination under the microscope, we enjoyed the assistance given by members of the Eastman Kodak Company in Rochester, N.Y. The company also provided some of the photographs of cross-sections reproduced in this guide. I acknowledge their assistance with thanks.

Some staff members of the Picture Conservation Division working full-time on archival holdings other than photographs nevertheless assisted in the preparation of cross-sections of photographs. I would like to thank Anne Ruggles and Denis Roy, who also photographed screen patterns of additive color photographic plates. Current staff member Joe Iraci prepared further cross-sections for use in both the light microscope as well as in the transmission electron microscope (TEM). He also prepared and photographed individual silver grains from processed black-and-white negatives and prints for examination by TEM. This work considerably advanced our knowledge on the mechanism of the chemical degradation of image silver.

Brian Lesser reviewed the entire manuscript and provided the line drawings. The numerous photographs throughout the study guide were prepared by Brian Thurgood and Joe Iraci, who both tremendously improved the manuscript during the proofing stages.

The photographs from the collections of the National Archives of Canada at the beginning of each chapter, with the exception of those for Chapters 1, 2, 10, and 11, were printed by Brian Thurgood. Photographs at the beginning of Chapters 3, 4, 6, and 7 were printed from original negatives, whereas photographs for the remaining chapters were printed from copy negatives prepared by Brian Thurgood from vintage prints. I am grateful to all our contributors for their fine efforts, especially to Joe Iraci and Brian Thurgood.

I express my gratitude to my superiors at the National Archives of Canada for their long-standing support of our work. In particular, I thank Mr. Ken F. Foster, Director General of the Conservation Branch, for his continued interest in and support of this work. I would also like to acknowledge the assistance received from the Public Programs Branch in the production of this volume.

The series of photographs on the cover are by Dr. Edith Weyde, who during the 1930s studied the permanence of black-and-white photographic prints while working at the Agfa Company in Germany. [cf. *Photographische Industrie* **36** (18), 529-530 (1938)]. The photographs on the cover originate from that study. A few years ago, she donated a number of these experimental prints to the Photograph Conservation Laboratory at the National Archives of Canada. Dr. Weyde continued her work on the preservation of photographs during the next decades and maintained a keen interest in our field until her death in February 1989. I am grateful to her for sharing with us so much of her vast experience and for her freely given advice on numerous difficult occasions.

Klaus B. Hendriks
Ottawa, Ontario, Canada
November 1991

Molson Brewery after a fire. Montreal, Quebec. July 1852. Daguerreotype by T.C. Doane. Contemporary photographic reproduction in color. National Archives of Canada/C-0089689.

1 Photograph Conservation Training Program

1.1 Introduction

This training manual grew out of the experience of staff members teaching fundamental methods and techniques of photograph conservation to students and interns in the Picture Conservation Division of the National Archives of Canada. During a period of 12 years, more than 40 different individuals worked in our Photograph Conservation Laboratory for periods varying from four months to more than a year. Several returned after their first term for a second and third work period in order to increase their expertise. None of these interns had any experience in the conservation of photographs, but our laboratory rules required that they have certain credentials, i.e., a background that includes formal training in either fine art conservation (with emphasis on paper documents), or in photographic technology, or in chemistry. Training in fine art conservation is provided in Canada by the Master of Art Conservation Program at Queen's University, in Kingston, Ontario, as well as by a number of smaller colleges. There are about half a dozen similar academic programs teaching the conservation of cultural property in the United States of America. Ryerson Polytechnical Institute in Toronto, Ontario, is the only college in Canada that offers courses in photographic technology, but there are several such colleges in the U.S., of which the Rochester Institute of Technology is perhaps the best known. Chemistry can, of course, be studied at almost any college or university. We recommend that individuals who intend to follow the training sequence (program) outlined in this manual receive formal training in at least one of the above-mentioned disciplines.

Throughout the manual we refer to the user of this guide as student. We use the term student in its widest sense, i.e., as designating a person who wishes to learn something by doing it and by studying. It does not matter whether that person is employed by a cultural institution, is a student in a conservation course, or is working through this manual on his or her own.

1.1.1 Scope of the Training Manual

The objects discussed in this manual are, for the most part, still photographic images in the form of negatives and prints. They may be in monochrome or in color. These images may be made by silver halide processes or by non-silver processes. Information on specific properties of photographic materials has often been obtained from experience with other types of photographic records. Examples include the description of the properties of cellulose nitrate films in the motion picture film literature; a landmark article on the preservation of color motion picture films using cold storage, a technique that is applicable to other color photographic records as well; discussions on the stability of polyester film base, which can be found in the literature on aerial photography; and the degradation of image silver by a chemical oxidation reaction, which was first observed and examined on processed microfilms. Consequently, the student will find in this manual bibliographic references to these and other photographic materials that are not part of the scope of this manual. The study of all types of photographic records contributes to a widening of our knowledge and understanding of the behavior of still photographic images. In addition, there are a few notes on the storage of processed microfilm whose presence has become so common in archives and libraries.

Although some experiments involve both black-and-white and color images — such as one on the soaking and drying of photographs — there are none especially designed for color photographs. Data about the fading of photographic images are obtained from the published literature. Since the degradation of dyes is thought to be irreversible, the prime concern becomes the prevention of such degradation through correct storage and display conditions. The duplication and copying of color photographs is not included in this book, as it is a specialized field of its own. At any rate, most conservation laboratories are not equipped to carry out the processing of color films and prints.

This manual offers extensive discussions of all aspects of a conservator's duties and provides approximately 70 laboratory experiments, to give the student both the theoretical knowledge and practical skills to perform a wide variety of activities. These include: cleaning and repairing damaged photographs and negatives; copying and duplicating deteriorating images; testing materials for stability; and preserving photographic records so that they may be used by researchers.

Our experience in training photograph conservators to deal with the collections of the National Archives of Canada has led us to identify the most important areas of study that are necessary for the successful and responsible treatment of photographs. These are:

1. The study of the history of photography and photographic processes, to gain an understanding of the photograph's nature, the relative historical and artistic value of the pictures made by various processes, and the physical properties of the many and various

processed photographic materials commonly found in collections. In this study guide, much of this preparation takes the form of readings in the history of photography and photographic technology, with reference to actual examples of 19th- and 20th-century processes from our study collection. To the extent possible in our laboratory, we teach the student about the characteristics and responses of various photographic processes by actually preparing various early light-sensitive materials for use in studies and tests.

2. The application of conventional prints and drawings conservation techniques to photographs: cleaning (dry and wet); removal of tapes and adhesives; "relaxing", flattening, and encapsulation of photographs; dismounting images from acidic and brittle backings; laying down weakened images on new supports; repairing torn or otherwise damaged images; mounting and matting images for display and storage. These are the treatments most often requested by curators and required by the object itself. It is an area in which many conventionally trained paper conservators with only a limited knowledge of photographic materials find themselves called upon to carry out practical work. In addition, there are treatments specific to photographs, for example, the transfer of an emulsion layer, or image layer, from a degraded support to a new and stable base, or the repair of broken glass plate negatives.

3. The application of selected aspects of photographic technology and sensitometry. A thorough knowledge of sensitometric responses of films and papers, and the ability to establish and maintain appropriate processing controls and procedures, is absolutely essential to the training of photograph conservators, who may be called upon to treat collections containing rapidly deteriorating cellulose nitrate and cellulose diacetate negatives, broken or damaged glass-plate negatives, and badly deteriorating prints. These images must be duplicated to save the content of the photograph. Sensitometric measurements are used throughout the experiments of this manual to monitor the performance and quality of such work.

4. The application of selected aspects of photographic science, such as knowledge related to the manufacture of photographic plates, films, and papers, to carry out the various methods of testing support materials (glass, paper, plastic film), binding media (gelatin, collodion, albumen), and image-forming substances (elemental silver, dyes, certain metal salts), for accurate identification, to determine their long-term stability and to assess their condition before undertaking certain treatments. This background in photographic science assists the conservator in judiciously proposing and carrying out treatments on photographic images. In addition to those basic treatments carried out

by conventionally trained prints and drawings conservators, certain remedies and preservation measures (such as treating mouldy or flaking gelatin emulsions, detaching gelatin emulsions that may have become stuck to other emulsions or to their paper enclosures, stabilizing broken or cracked glass-plate negatives) rely for their success on the conservator's in-depth understanding of the special characteristics of photographic materials and their likely responses to particular treatments. This study guide provides a minimum level of background in this crucial area of knowledge, which is often given only superficial treatment or is missing altogether in existing photograph conservation courses and workshops.

5. Photographic chemistry, as it applies to the restoration in chemical solutions of discolored and stained photographic negatives and prints. Such chemical restoration is at an experimental stage at the Photograph Conservation Laboratory. The present rather labor-intensive treatment methods make it appropriate only for selected images, rather than for large numbers of images, although the goal is to develop reliable methods that can be used with larger collections.

We expect that students who wish to follow this laboratory guide will have some, but not all, of these necessary background areas. This program is specifically designed to remedy deficiencies in training and experience in one or more of these critical areas. Extensive readings and practical laboratory exercises are structured to provide knowledge and skills for those who may be lacking extensive scientific background, or for those who may have no training in paper conservation techniques.

At the Photograph Conservation Laboratory, we make a distinction between photographic materials (negatives, prints, and positive transparencies in black-and-white and color) in an archive, historical repository, library, or museum, and those in a fine art collection, such as may be found in the National Gallery of Canada, the Canadian Museum for Contemporary Photography, the Museum of Modern Art in New York City, or the Art Institute of Chicago. These latter collections usually contain predominantly positive reflection prints that have been acquired from photograph dealers and auction houses in relatively good condition. Fine art collectors often seek the guidance of photograph conservators to determine the proper archival housing, storage environment, and benevolent display conditions for images in their domain. Fine art curators may draw up guidelines for the handling, copying, lending, and exhibiting of photographs, based on the results of conservation laboratory research. But these fine art collections are relatively small and manageable, sometimes fewer than 1,000 images, rarely more than 100,000. Their most common preservation need is for mounting, matting, and appropriate storage containers.

In an archive, museum, or library, however, the acquisition process is more often weighted in favor of the photograph's historical or documentary value, with less initial concern about the physical condition of the objects acquired. The mandate to preserve these artifacts often moves repositories to save from possible destruction single items and large collections that previously have been stored under the most unfavorable conditions. These images and collections usually pose more serious preservation problems. Often, too, archives, by agreement, must provide housing and bibliographic control for photographs transferred from various government agencies, private organizations, and manuscript collections, in addition to numerous private donations of photographs and those items purchased for the collections. Consequently, there are often millions of photographic images in these repositories, some undoubtedly categorized and valued as fine art or master photographs, but far more being primarily of historical or documentary importance.

The photograph conservation training guide, inasmuch as it grew out of and reflects the needs and priorities of the National Archives of Canada, attempts to prepare conservators to deal with the range of preservation problems found in these larger historical collections. Thus, we include a discussion of methods for surveying large collections for overall preservation and housing needs, as well as methods for assessing and reporting on the condition and appropriate treatment for single images that are singled out as requiring more extensive treatment.

Some historical images in these large collections exist in many copies, or come to the National Archives as duplicate images, so that they can be used for experimental purposes. These materials, which would otherwise be discarded by curators, have played an important role in our ability to learn about various photographic processes. From the emphasis on laboratory work in this training manual, it will be clear that the philosophy of our laboratory is to encourage experimentation for the purpose of studying the properties of the various photographic processes, examining their permanence characteristics, and exploring new ways of restoring, duplicating, or copying those that have suffered damage. A second source of obtaining photographic pictures made by obsolete and historical processes is to prepare them in the laboratory. This manual contains detailed procedures for producing five different types of historical photographs.

Laboratory experiments in the conservation treatment of photographs described in this manual are neither standard treatments nor are they generally approved or agreed upon. However, all of them have been carried out in our laboratory — most of them repeatedly — and were found to be meaningful and instructive. As the field of photograph conservation develops, some of our proposed experiments may be replaced by better ones, while others may be added. This manual does not describe all treatments that are possible, for it must be said, at the outset, that there are certain treatments that we do not yet carry out in our laboratory, such as autoradiographic copying. The manual is designed to be updated on a regular basis, so that new treatment methods may be taught in the future within this context. Similarly, information about presently unsettled and controversial areas (which are discussed herein) will be revised as new findings occur. In any event, an extensive bibliography includes articles on those areas not discussed extensively in this manual.

In the Photograph Conservation Laboratory, we feel strongly that a co-operative spirit between curators and conservators must be encouraged. The conservator should respond to those immediate and long-range preservation problems of concern to the curatorial staff and should propose feasible solutions. The curator should call the conservator's attention to particular preservation problems and, to the extent possible, should apply the conservator's findings and recommendations when choosing storage enclosures, planning and arranging storage environments, and developing guidelines for the physical handling and display of the collection.

The conservation of photographs is not yet a well-established or coherent body of knowledge. This laboratory manual aims to develop a relevant and thorough course of theoretical and practical training that provides a systematic approach to the problems of preserving individual photographs or photographic collections. Photograph conservation skills are now in increasing demand by museums, archives, and libraries, due to our increasing awareness of the value of photographs as historical artifacts. We hope that this guide will contribute to the acknowledgment of the field of photograph conservation as a legitimate specialization, which requires the establishment of high standards for training and for the critical evaluation of work carried out by photograph conservators. Curators and collection administrators have a right to expect knowledgable and responsible treatment of objects under their control. By providing a thorough laboratory manual that prepares the conservator to deal with both common and unusual problems found in collections, we hope to assist in the establishment of professional standards for the training of future conservators.

We would like to emphasize that while this laboratory manual (with its descriptions of photographic processes and discussion of the guidelines for the preservation, storage, and display of photographs) may play an informative role for curators and conservators of traditional prints and drawings, in our opinion there is no substitute for the practical laboratory experiments, the close supervision while carrying out specific treatment methods, the discussion of particular laboratory results, and the recommendations for intensive and historical readings that make up the actual training program.

At the beginning of each chapter the reader will find the reproduction of a photograph from the collections of the National Archives of Canada. These images, while representative of this country's history and the nature of this institution's holdings, remind us of our primary goal: to preserve them for future generations to study and enjoy.

1.2 Literature Study

PHOCUS

An awareness and understanding of the history of the photographic medium and the properties of images made by historical processes is essential to a thorough training in the conservation of photographic materials. Contemporary scientific research on the stability and preservation of photographic records should be monitored closely. Research being conducted by the Photograph Conservation Laboratory is firmly based on excellent work from around the world that has preceded our own investigations. Students in our laboratory are given full access to the collection of more than 9,000 research articles and technical and historical books related to the subject of photograph conservation. These reference materials are gathered together in the bibliographic data base called *PHOCUS*, which is managed by the National Archives Library. In the summer of 1988, a majority of the references collected in *PHOCUS*, (about 6,500) were transferred to the Conservation Information Network (CIN) to become part of that data base. Access to these references on the stability and preservation of photographic records is now available to the subscribers of CIN.

Photograph Conservation Source Book

A selection of the most important articles and technical brochures has been assembled in an in-house manual, the *Photograph Conservation Source Book* (*PCSB*). In the *PCSB* will be found benchmark articles, published and unpublished research papers, ANSI Standards, and technical and scholarly publications which provide not only a cross-section of both historical and contemporary research, but also a good reference source for formulae and details of working procedures.

Photograph Conservation Study Collection

Part of the teaching equipment of this laboratory is the *Photograph Conservation Study Collection*, consisting of sample photographs made by historical and common photographic processes. These sample photographs, mounted and clearly identified, can be handled and viewed front and back and under different angles by the interested student for purposes of identification by comparison with other photographic images. We highly recommend that any institution seriously devoted to the preservation of its photograph holdings put together such a study collection, since it has proven to be invaluable in studying and identifying various photographic materials.

References

The reader will find after each chapter a list of references that have been mentioned specifically in the preceding text. This is followed by a general reference list that offers additional reading on the chapter's topic. The general reference list at the end of Chapter 1 mentions well-known handbooks on the science and technology of photography; they contain a wealth of useful information and therefore should be kept close at hand and consulted frequently. The recommendation to study these handbooks demonstrates our approach to the preservation of photographs: as products of a highly developed technology, photographs have properties that can be measured and monitored. Consequently, their preservation is a matter of precisely determining the causes of their deterioration and attempting to prevent or even correct it.

In summary, this laboratory manual reflects the experience, knowledge, and priorities of the Photograph Conservation Laboratory at the National Archives of Canada. The development of our thinking has taken certain directions that were shaped by the nature of this institution's archival holdings. Emphasis in photograph conservation is placed on silver gelatin photographic materials, by far the most numerous in our collections. The choice of experiments described in this manual has been influenced by the equipment available in our laboratory for testing or restoring. Although not all of this equipment may be present in other laboratories, the reverse may also be true: that other laboratories enjoy the use of instruments and devices not available to us. This manual is subject to be amended any time by adding new experiments or modifying existing ones.

1.3 Bibliography of Basic Texts and Laboratory Manuals

Certain basic reference books are cited again and again within the training manual. The following bibliography includes books of a general historical nature, as well as basic photographic science works. Our emphasis is on those works that provide the most technical background within a photo-historical context. The student should be familiar with these works and should consult them frequently, in addition to those references cited in each chapter.

Coe, Brian, and Mark Haworth-Booth. 1983. *A Guide to Early Photographic Processes.* London: Victoria and Albert Museum and Hurtwood Press.

Crawford, William. 1979. *The Keepers of Light.* Dobbs Ferry, N.Y.: Morgan & Morgan.

Eder, Josef-Maria. [1945, 1972] 1978. *The History of Photography.* Trans. by Edward Epstean. [New York: Columbia University Press]. Reprint: 4th ed., New York: Dover.

Gernsheim, Helmut and Alison. 1969. *The History of Photography: From the Camera Obscura to the Beginning of the Modern Era.* New York: McGraw-Hill.

Haist, Grant. 1979. *Modern Photographic Processing.* 2 vols. New York: John Wiley & Sons.

Jacobson, Ralph C. 1978. *The Manual of Photography*. London: Focal Press Ltd.

James, T.H., and G.C. Higgins. 1968. *The Fundamentals of Photographic Theory*. 2nd ed. Dobbs Ferry, N.Y.: Morgan & Morgan.

Newhall, Beaumont. 1964. *The History of Photography, from 1839 to the Present*. 4th ed. New York: Museum of Modern Art.

Reilly, J.M. 1986. *Care and Identification of 19th-Century Photographic Prints*. Kodak Publication, no. G-2S. Rochester, N.Y.: Eastman Kodak Co.

Stroebel, L., et al. 1986. *Photographic Materials and Processes*. Boston: Focal Press.

Sturge, John M., ed. 1977. *Neblette's Handbook of Photography and Reprography Materials, Processes and Systems*. 7th ed. New York: Van Nostrand Reinhold.

Sturge, John M., et al., eds. 1989. *Imaging Processes and Materials: Neblette's Eighth Edition*. New York: Van Nostrand Reinhold.

Todd, H.N., and R.D. Zakia. 1974. *Practical Sensitometry: The Study of Tone Reproduction*. 2nd ed. Dobbs Ferry, N.Y.: Morgan & Morgan.

Woodlief, Thomas, Jr., ed. 1973. *SPSE Handbook of Photographic Science and Engineering*. New York: John Wiley & Sons.

Unidentified Six Nations Chief. ca. 1860s. Ambrotype by unknown photographer. Contemporary photographic reproduction in color. National Archives of Canada/C-0084932.

2 Darkroom and Laboratory Equipment and Procedures

2.1 Introduction to the Photograph Conservation Laboratory

The Photograph Conservation Laboratory serves several purposes within the National Archives of Canada. These are:

1. To conserve photographic materials from the Documentary Art and Photography Division.
2. To provide curators and archivists with information concerning preventative conservation methods and technical information on historical and contemporary photographic materials and processes.
3. To provide photographic expertise and equipment for treatment documentation for the Picture Conservation Division staff.
4. To provide for curators and archivists, for special occasions or purposes, high-quality transparencies of works of art for study purposes and publications.
5. To carry out research regarding the stability of photographic materials, to copy and duplicate historic materials, and to conduct research into photograph conservation procedures.
6. To train photograph conservators, so that they will be prepared and available to address the preservation and conservation needs of the historical and artistic photographs in the Documentary Art and Photography Division.

Meeting this wide range of needs requires a variety of equipment and resources that traditionally belong in at least one of the three overlapping areas of conservation, photography, and scientific research. Some conservation equipment that would be required for a prints and drawings conservation laboratory are not required in a photograph conservation lab. On the other hand, a great variety of cameras, processors, and other photographic equipment is needed to fulfill all the needs of treatment documentation, production of transparencies for study purposes, and research in areas such as the stability of photographs. Another resource required for the conservation and educational requirements of the

Photograph Conservation Laboratory is a study collection of samples of various photographic materials and processes that is maintained in the lab. The Picture Conservation Division also has access to the *PHOCUS* data base bibliography, which provides the most complete listing of articles from technical and popular journals to be found anywhere on the subject of photograph conservation.

While using this photograph conservation study guide, students are asked to take careful notes about the setup, adjustment, operation, and care of various pieces of equipment and apparatus used. Students are also advised to follow correct and safe laboratory procedures, such as the correct handling and labelling of chemicals.

This chapter is an introduction to the equipment and procedures of the Photograph Conservation Laboratory. In describing the equipment in the laboratory, we refer to certain kinds and makes of equipment that we have used successfully. This does not imply that other brands of equipment are inferior or that the equipment described is the most suitable for the needs of any lab outside our own.

2.2 Photographic Studio Equipment

The photographic studio contains essential equipment for three important functions of the photograph conservation lab:

1. The photo-documentation of works of art before, during, and after treatment.

2. The copying and duplication of photographic prints and negatives.

3. The preparation of original photographs and test targets for testing and research purposes.

Materials and Apparatus

- 35-mm cameras and lenses:
  - Nikon F 35-mm camera
  - Nikon F-3 35-mm camera
  - Canon EOS 650 35-mm camera
  - Micro-Nikkor-P.C. Auto 1:3.5 55-mm lens
  - Nikkor 28-mm 1:2 lens
  - Canon zoom lens EF 28-70-mm 1:3.5-4.5
  - Canon zoom lens EF 70-210-mm 1:4
- 4" × 5" camera and lens:
  - Sinar P
  - Schneider-Kreuznach Symmar S 5.6/150-mm
  - Polaroid back
  - film holders
- 8" × 10" camera and lens:
  - Sinar P
  - Schneider-Kreuznach Symmar S 5.6/300-mm
  - Polaroid back
  - film holders
- camera stand tripods
- back drops
- studio lights: Kodak Pola-light Model 2 115V 500 watt 3200°K bulbs
- flash system: Broncolor Impact 41 output; 300J
- 35-mm copy stand and camera:
  - Leitz Reprovit IIa
- slide copier Kenro Spectra 1000 with Nikon F-3 and Rodenstock Trinar 75-mm 1:4.5 lens

- easel
- light box: MacBeth Prooflite 510 D5000 Standard Viewer
- macro equipment
- grey scales
- resolution targets
- MacBeth color rendition guide
- camera filters
- lintless nylon gloves

The 35-mm camera, macro equipment, Reprovit IIa, and slide copier are all used for documentation and to produce test and target materials. The small format negative is generally not suitable for copying. On the other hand, the larger format cameras, 4" × 5" and 8" × 10", may be used for any of the three main functions listed above. Care in handling the cameras and particularly the lenses is necessary in order to allow the production of high-quality negatives and transparencies. In particular, shutters must be left in the position of lowest tension and lenses must be covered with their lens caps or put away when not in use. Do not attempt to clean or repair any equipment or lenses without consulting an instructor. Avoid cluttering the studio and handle all targets and originals with care. In particular, the surface of a target such as the MacBeth color rendition guide should never be touched by human skin.

The setup and usage of studio equipment for copying is described in the chapter on duplication and copying.

2.3 Darkroom Processing Equipment and Methods

The preparation of documentation photographs and of samples for materials evaluation requires extensive darkroom and processing facilities to produce high-quality negatives, positive reflection materials, and transparencies. A basic list of necessary equipment, divided into equipment used for exposure and that for processing, follows.

Equipment Needed for Exposure

- light-proof room
- Kodak Process Control Sensitometer Model 101
- NuArc point light source
- contact printing frame
- condenser enlarger: Omega Pro-Lab 4" × 5"
- diffusion enlarger: Omega Super Chromega D Dichroic II
- enlarger lenses: Rodagon 150-mm 1:5.6
  80-mm 1:4
  50-mm 1:2.8
  Omegaron 150-mm 1:3.5
  90-mm 1:4.5
  50-mm 1:4.5
- easels
- light table
- dust removers and static eliminators
- timers

Equipment Needed for Processing

- safelights with filters
- Table-top processors:
  Hope 152 Black-and-White Film Processor
  or:
  King Concept Corporation Enterprise Photo Processor (This machine can process B/W, C-41, and E-6 in 35-mm format up to 16" × 20")
- For manual processing:
  Pyrex glass and plastic processing trays in the following sizes:
    5" × 7"
    8" × 10"
    11" × 14"
- open tank line for sheet film processing
- 35-mm film developing tanks and reels
- print tongs
- rocker table
- water temperature control system
- archival print washer
- film washer
- tray siphons
- film drying area
- print dryer
- drying screens
- containers for prepared chemicals
- amber glass and polypropylene
- rubber gloves

Before discussing processing procedures, we will describe the equipment used for darkroom exposure.

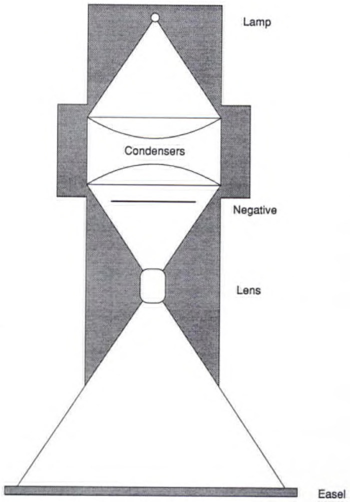


Fig. 2.1: Condenser enlarger.

Enlargers

There are two basic types of enlargers, *condenser* and *diffusion*. The correct use of either type of enlarger requires that negatives to be printed be exposed and processed correctly for the particular type of enlarger. Negatives to be printed on condenser enlargers are usually given more exposure and less development than negatives to be printed by contact or with a diffusion enlarger (Eastman Kodak, 1987). Correctly exposed and processed negatives may produce acceptable photographs with either type of enlarger, but certain types of work may require one particular system for best results. (For the experiments described in this guide, the preferred enlarger is specified.)

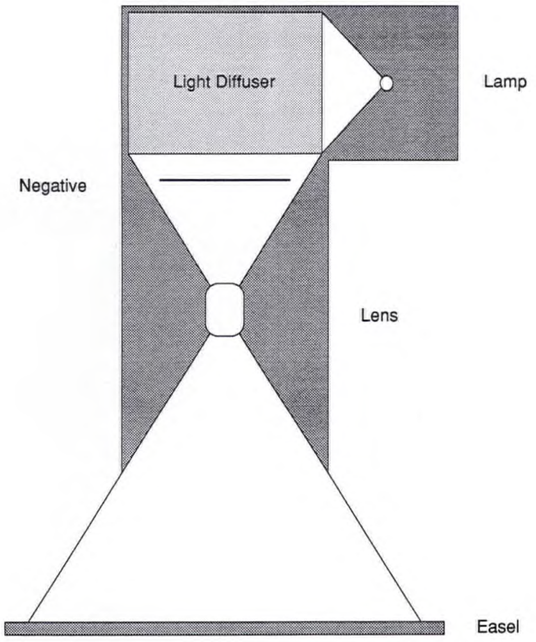


Fig. 2.2: Diffusion enlarger.

In a *condenser enlarger,* a large glass optical condenser sits between the negative and the incandescent (or quartz halogen) light source, to provide even illumination across the entire surface of the negative. The condenser diameter must be at least equal to the diagonal of the largest negative to be used in the enlarger.

Condenser enlargers give increased tonal separation and accentuate blemishes and the grain of the negative, due to the directed light rays that illuminate the negative. Printing contrast is thus higher than when printing by contact or when using a diffusion enlarger (Jacobson, 1978).

Diffusion enlargers consist of a light source above a diffusing screen made of opal or ground glass or directed through a diffusing "box." These enlargers will produce prints similar in contrast to those produced by contact printing depending in particular on the degree of flare.

Diffusion enlargers tend to subdue the effect of scratches and grain size, due to the scattering of the light by the diffusion screen. Diffuse illumination of the negative results in a lower contrast print than would be obtained from a condenser enlarger (Jacobson, 1978). A popular version of the diffusion enlarger is the "cold-light" source, which uses fluorescent rather than incandescent light.

Contact Printing Equipment

The printing and processing of historic materials for optimum reproduction requires consistent and repeatable procedures. Good results depend initially on the evenness of illumination of the negative. Because uneven illumination can result in inaccurate tonal ranges in the duplicate negative or copy print, we measure the evenness of illumination on the film plane prior to exposure, using a footcandle meter. Because we use large-format cameras and sheet films for much of our critical copy work, we can often better ensure even illumination by contact printing these negatives, using a point light source.

The *NuArc point light source* is a controlled source of light to be used for contact printing, in conjunction with a printing frame. A lamp with a conical shade directs the light evenly down onto the exposure plane. The power supply can vary

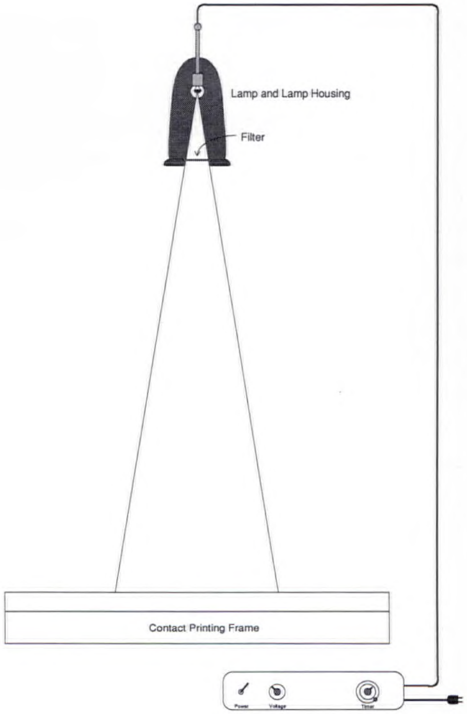


Fig. 2.3: Point light source and contact printing frame.

the intensity of the bulb without affecting the evenness of illumination. Care should be taken to ensure that the exposure plane is perpendicular to the light source. The evenness of illumination across the exposure plane should be checked with a footcandle meter.

A *contact printing frame* consists of a frame, a sheet of glass, and a spring-loaded back to provide even overall pressure. The negative is placed on the glass, with the emulsion away from the glass. The paper is placed on top of the negative, with the paper emulsion facing the negative emulsion. The back of the printing frame is fastened into place. This package is then inverted and exposed under the point light source. All contact exposures unless otherwise noted in this manual are done in this way so that the emulsions of the two materials are in direct contact with each other.

Sensitometers

A sensitometer provides precise and repeatable exposures of photographic materials. They are commonly used for process control work or whenever consistency of exposure time, intensity and the color of the light source are important. Sensitometers consist of a calibrated light source, a filter housing to accommodate neutral density and color correcting filters, a shutter, and a light modulator (step tablet) to provide varying degrees of exposure on the sample. Figure 2.4 illustrates the basic parts of a typical sensitometer. The light source in the Kodak model 101, used in this laboratory, requires occasional calibration. This is done by determining the lamp current that produces the correct intensity of light from the sensitometer lamp. The correct current is listed on the side of the machine beside the ammeter, which displays the lamp current. Whenever the sensitometer is turned on, the lamp control knob must be adjusted to give the correct current. The device is then allowed to stabilize for three minutes, and the current is adjusted a second time, if necessary.

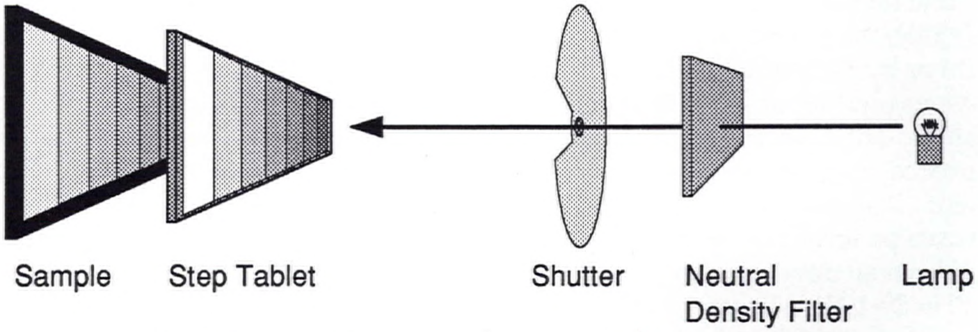


Fig. 2.4: The main components of a sensitometer.

2.3.1 Standard Photographic Processing Methods

Introduction

The processing of photographic films and paper can be carried out in several ways, but some methods offer more even development and more consistent, reproducible results than others. For consistent development over large areas of a film sheet, optimum results are obtained by passing the film through processing solutions (as in the roller transport method) rather than moving solutions around the film (as in the tray, tank, or reel systems). Roller transport processors may, however, produce subtle streaks in images.

To the extent possible in our laboratory work, we match the processing method to the degree of control required in a particular experiment or application. Photograph conservators should be familiar with all common processing methods, however. Later in the training guide (Sections 4.3.1 and 4.4.1), students will have the opportunity to gauge precisely the effect of various agitation and development methods on the evenness of development. The following summary of these methods provides a brief introduction.

1. *Tray processing* (for sheet films and papers) requires the use of four or more processing trays, slightly larger than the materials to be processed, one for each of the following steps: developer, stop bath, fixer, and washing aid or hypo clearing bath. Each tray should have its own set of tongs to avoid contamination. Tray processing requires a set agitation procedure to ensure evenness of development. If agitated incorrectly, standing wave patterns can be set up, resulting in uneven development. ANSI Standard PH4.29-1986, *Methods for Manual Processing of Black-and-White Photographic Films, Plates, and Papers,* completely outlines the correct procedure.

2. *Closed tank and reel processing* (for 35-mm and 120-roll film) requires film to be loaded (in total darkness) onto a spiral reel that keeps the length of film from touching itself and allows processing solutions unimpeded access to all film surfaces. The reels are stacked on top of each other in a cylindrical light-proof tank, which can be used in the light after closing. Developer, stop bath, fixer, and washing aid are poured into and out of the tank in turn. Because of the time needed to fill and empty the tank, short development times can result in uneven development with this method.

3. *Open tank ("dip-and-dunk") processing* (for sheet films) uses a series of tanks, holding developer, stop bath, fixer, and washing aid. Each sheet of film is placed in a holder, groups of holders are suspended on a rack, and the rack is dipped in each tank in turn. The film is immersed in each solution and then lifted out at regular intervals. As the film is raised out of the solution, the top of the film drains first and is therefore in actual contact with the developer for less time than the bottom of the film. This results in some degree of uneven development.

4. *Nitrogen-burst open tank processing* (for sheet films) is a method that uses the same holder and rack suspension system for sheets of film as the manual open tank processing method. However, agitation for processing solutions is caused by the release of nitrogen gas from the bottom of the tank at set intervals. Although development results tend to be more consistent than with manual methods, uneven development may occur because of variations in the amount of solution agitation from one side of the tank to the other and from the bottom of the tank to the top.

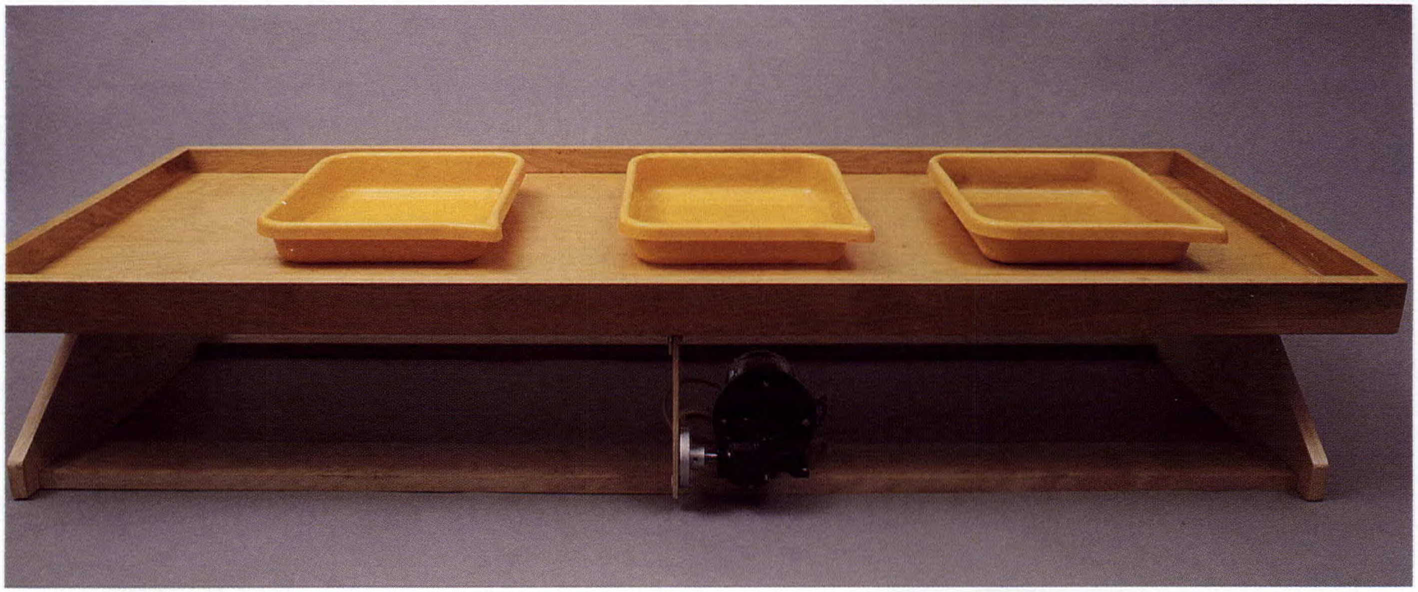


Fig. 2.5: Rocker table used to provide automatic agitation of solutions in trays. Although it does not provide adequate agitation for development, a rocker table is a great convenience when fixing or toning photographs.

5. *Roller transport systems* transport roll films or sheet films through the developer and subsequent processing solutions at an even rate. With the proper monitoring and replenishment of developing solutions in the system, this method results in consistently even development and thus is essential for experimental work, where reproducible results are essential. Our ability to copy or duplicate large batches of photographic prints and negatives from collections will depend on this consistency. Unfortunately, few of these processors sufficiently wash the negative. It is often necessary to either remove the negative before it reaches the drying stage and wash it separately or take the negative after machine drying and fix, hypo clear, wash, and dry it again.

Film samples in our laboratory are prepared using a Hope 152 Black-and-White Film Processor. Although this equipment is mentioned throughout the text, other processing methods can be used.

Print and Film Washers

Print washing is carried out in a large basin with a siphon, or in an archival print washer for those applications requiring a more thorough wash. *Film washers* for roll films consist of a cylindrical container that carries fresh water over all film surfaces. Sheet films may be washed with either a tray and siphon or archival washer, as with prints.

Dryers

Print and film dryers must provide a dust-free atmosphere. Dust settling on wet emulsions becomes stuck as the emulsion dries and hardens. Dust on negatives appears as white spots on the photographic print. Film should be hung to dry in a special closed, dust-free cabinet through which filtered air circulates. Prints should be air dried on fibreglass screens, or on clean photographic blotters. The use of heated metal platen dryers may damage certain emulsions, and the cover cloth that secures the print to the drying surface quickly becomes contaminated with residual processing chemicals. Some dryers employ warm air blown across the print surface, particularly those designed for resin-coated papers. With all methods other than the metal platen dryers, the emulsion of the print should face down.

Fig. 2.6: Archival print washer.

TABLE 1: SUMMARY OF PROCESSING SEQUENCES *

STEP	FILM	FIBRE-BASE PAPER
1. Development	Varies according to film type and manufacturer's recommendations: 4 to 12 minutes; agitation at regular intervals.	Between 60 and 120 seconds; constant agitation.
2. Stop Bath	15 seconds.	30 seconds.
3. Fixing	5 minutes in a hardening fixer; 2 minutes in a rapid non-hardening fixer; agitation at regular intervals.	For most prints, use two fixing baths, the second of which must contain fresh fixing solution: 5 minutes in each with regular agitation.
4. Washing	i. Rinse for 5 minutes. ii. Treat in hypo clearing agent for 2 minutes. iii. Wash for 5 minutes.	i. Rinse for 5 minutes. ii. Treat in hypo clearing agent for 3 minutes.[1] iii. Wash for 20 minutes.[2]
5. Toning	i. Treat in Eastman Kodak Rapid Selenium Toner (dilution 1:20) for 3 minutes. ii. Wash for 10 minutes in running water.	i. Treat in Eastman Kodak Rapid Selenium Toner (dilution 1:20) for 3 minutes. ii. Wash for 20 minutes in running water.
6. Drying	Dry, suspended in air in a dust-free environment.	Dry, emulsion side down, on a fibreglass screen in a dust-free environment.

Notes

1. Hypo clearing agent treatment times are for double-weight papers. They can be shortened by one-third to one-half for single-weight papers.
2. Washing times are for double-weight papers. They can be shortened by one-third to one-half for single-weight papers.

* It is often necessary to have a means of predicting the permanence of photographs as a consequence of their processing.This is done in practice by either analytically determining the amount of residual processing chemicals present in photographs or through applications of a technique known as accelerated aging. Higher temperatures and humidities that would be encountered in normal usage can be used for testing. This technique assumes that the reactions that lead to deterioration can be made to occur faster by increasing the addition of energy to the system (ANSI, 1986). For further information, refer to Section 4.5.

2.3.2 Basic Film and Paper Processing Procedures

Before using any photographic material, the manufacturer's processing directions should be consulted. These directions should be followed. In the absence of manufacturer's recommendations, the basic procedure for processing described in *Table 1: Summary of Processing Sequences* on page 25 should be used.

Processing of Resin-Coated (RC) Papers

The paper support in resin-coated (RC) papers is coated on both sides with a thin layer of polyethylene plastic. One side is then coated with the silver halide gelatin layer, which forms the photographic picture. The plastic coating gives these resin-coated papers properties similar to those of films: the processing solutions cannot be soaked up by the paper base. A typical processing sequence comprises the following steps: development for 60 seconds; rinsing in water; fixing for 30 seconds; washing two minutes; and drying in a special electrical dryer for 30 seconds. Total processing time: four minutes. Some manufacturers make processing machines for RC papers and have the developer already built into the gelatin layer (developer-incorporated papers). These processors make a well-processed dry RC paper print in 55 seconds. Although selenium toning increases their image stability, resin-coated papers should not be used for pictures that are intended for long-term preservation.

2.4 Photographic Materials Testing Equipment

Materials testing equipment is used to evaluate the nature of photographic materials and processes, and to gauge and monitor the effects on photographs of various treatments, storage conditions, and display conditions. Some of this equipment, such as light microscopes, is standard in scientific laboratories, but some devices such as the melting point apparatus, scratch resistance tester, wet abrasion tester, and the swellmeter must be specially assembled. These latter four devices are designed to test in some way the gelatin layer of photographic materials.

Materials and Apparatus

- microscopes:
  - Zeiss Universal Research Microscope
  - Zeiss Stereomicroscope
  - Philips EM-300 Transmission Electron Microscope
- densitometer: MacBeth TR924 (reflection and transmission)
- melting point apparatus
- wet abrasion (mushiness) tester
- scratch resistance tester
- swellmeter, with plotter and printer

Fig. 2.7: Stereomicroscope.

Fig. 2.8: MacBeth TR924 reflection and transmission densitometer.

A compound microscope is often used to examine samples but in this study guide is discussed mainly as a tool for observing imaged resolution targets on test samples and determining their resolution. The transmission electron microscope (TEM) is mentioned as it allows us to observe and photograph the structure of processed silver grains but will not be used in the experiments in this guide. The stereomicroscope is particularly useful for identifying historical photographs and for examining the surfaces of samples.

The standard method of measuring the degree of blackness or saturation in color photographs after they have been exposed and processed is to measure their density (see Chapter 4) with a photoelectric densitometer. There are two basic kinds of densitometers, reflection and transmission. A reflection densitometer is used to read the density of positive reflection print materials and is also used for other images with an opaque base. Transmission densitometers are for negatives and other materials with a transparent base. Often, as in the case of the MacBeth TR924, densitometers may be equipped to read in both reflection and transmission modes.

At the very least, most densitometers are capable of reading visual or photometric density. This is made possible by a filter in the densitometer that, combined with the detector in the device, yields an overall spectral response similar to that of the human eye. When information about the color of a sample is desired, readings are taken through one of two sets of special color filters. The first set, referred to as Status A filters, is designed for reading direct reversal materials such as positive transparencies and color print materials. The three color densities read are red, green, and blue. Status A filters may be used for any photographic material that is to be directly viewed. Materials such as color negatives, which are not intended for direct viewing but for printing, are measured with Status M filters, which give red, green, and blue densities. Of course, in both transmission and reflection modes of the densitometer, a visual density filter is also available that may be used to determine photometric density.

2.5 Prints and Drawings Conservation Equipment

Conservation treatments performed on photographic materials have been derived primarily from traditional prints and drawings conservation techniques. Removal from mounts, wet and dry cleaning, repairs, infills, stain removal from paper supports, retouching, matting, framing, and the construction of protective housings are all procedures applied to paper-based objects. Emulsion transfer, repair of cracked and cupped emulsions, and repair of glass plates are treatments specific to photographs and derived from industry or have been developed in the photograph conservation lab. The techniques are discussed in Chapter 7. The equipment required to perform these treatments ranges from small hand tools (including scalpels, spatulas, brushes, etc.) to lab equipment and furniture (including balances, washing sinks, a purified water supply, a fume extraction system for toxic solvents, light tables, and large work tables) to lab glassware and paste-making equipment (including saucepan, hot plate, blender, beakers, graduated cylinders, etc.).

Fig. 2.9: Paper suction table.

A more specialized piece of equipment designed specifically for paper conservation is the paper suction table. The surface of the table consists of a series of stainless steel screens through which air is drawn. The object to be treated is placed on blotting paper and, due to air pressure, they are held in intimate contact with each other. Solvents, solubilized dirt, etc. are drawn through the object into the blotter by means of capillary action.

A pH meter with a surface probe is a standard piece of scientific equipment that measures the surface pH of paper. As acidity is one of the main contributing factors to the deterioration of paper, measuring the degree of acidity by pH readings provides an indication of the severity of the problem. Post-treatment readings provide an indication of the effectiveness of treatments such as washing and deacidification.

The following is a list of tools and equipment required for use in a photograph conservation studio:

Equipment

Small Tools:
- scalpels
- scissors
- straight-edge agate burnishers
- rubber roller
- graphic arts knife (for example, X-acto knives)
- pin tools
- swabs
- wrapped lead weights
- spatulas
- bone folders
- tacking irons
- tweezers
- magnifying device
- brushes:
  - retouching
  - pounding
  - paste
  - water

Fig. 2.10: Tools and equipment used for the conservation of photographs.

Miscellaneous Equipment:
- saucepan
- hot plate
- blender
- paste screen
- self-healing cutting base
- hot air gun

Glassware:
- beakers
- graduated cylinders
- glass stirring rods
- funnels
- solvent bottles
- pipettes
- eye droppers
- trays

Lab Furniture:
- fume hood
- washing sinks
- washing trays
- work tables
- storage cabinets
- plan file drawers
- light table
- water purification system

Analytical Equipment:
- stereomicroscope
- pH meter

Paper Conservation Equipment:
- board cutter
- mat cutter
- paper suction table
- ultrasonic humidifier

2.6 Chemistry Lab Equipment

A well-equipped chemistry laboratory is required for solution preparation and for most testing procedures carried out in conjunction with the conservation of photographs. Laboratory safety equipment should be a part of the chemistry laboratory. Safety procedures are discussed later in this section.

Materials and Apparatus
- analytical balance
- pH meter
- aging ovens
- glass desiccators
- microtome sample preparation equipment
- rocker table
- hot plate
- magnetic stirrer with stirring bars
- thermometers

Glassware:
- beakers
- trays
- test tubes
- flasks (volumetric and conical)
- funnels
- stirring rods
- pipettes
- graduated cylinders

Safety Equipment:
- fire blankets
- fire extinguishers
- respirators
- goggles

- safety glasses
- lab coats
- gloves:
    - polyethylene
    - Neoprene
    - asbestos
    - latex
- eyewash stations
- first aid kit
- chemical storage cabinets
- spill clean-up kits for acids and solvents
- rubber acid-transporting pails
- waste chemicals collection and disposal container
- fume hood
- material safety data sheets
- WHMIS labels (see Section 2.6.2)

2.6.1 Laboratory Procedures: Preparing Materials and Solutions

Chemicals required for an experiment should be set out before commencing the experiment. When you are ready to use a chemical for the preparation of a solution, follow the appropriate procedures depending on the nature of the reagent being used. For a solid substance (crystal or powder form), the reagent can be poured or shaken out onto a weighing boat or other suitable vessel that is already on a weighing scale that has been tared. Alternatively, powdered chemicals usually require a spatula to extract the reagent, so that very little potentially harmful airborne contaminants are produced. For a liquid, it is best to pour out a small amount into a clean beaker; from this beaker, the required amount is measured using either a graduated cylinder or, when more accuracy is necessary, a pipette.

Unused chemicals must not be returned to their original bottles or containers in order to avoid contamination of the bulk reagent. Instead, all wastes must be disposed of properly and lawfully. Organic solvents and solutions must be poured into an organic waste container for pick-up. If the solvents or solutions contain chlorinated materials, they must be put in the organic chlorinated waste container and stored until the waste is collected by waste disposal authorities. Many aqueous solutions can be disposed of down the sink, given the small quantities normally encountered in this type of laboratory. However, solutions that contain heavy metals (i.e., silver, lead, etc.) should be stored in glass bottles, appropriately labelled and placed in storage for disposal pick-up. If you are unsure about the disposal of a solid or liquid, consult the relevant authorities or *Material Safety Data Sheets* rather than simply throwing the substance down the sink or putting it in the garbage (see Section 2.6.2).

Certain common rules in the preparation of solutions must be followed to avoid problems either in laboratory safety or in the preparation of the solution itself. Firstly, distilled water is preferred for aqueous solutions and volumetric flasks should be used. Solids should be added to the water and not the opposite. The quantity of water initially should be about half of the final solution volume and the solid should be added to this, stirring with a magnetic stirrer and stir bar. After the solute (substance that is to be dissolved in the solvent) has dissolved, the solution is made up to the volume mark on the flask with distilled water. A solute must be completely dissolved before adding another and never should the order of mixing that is given in the formula be changed, since altering the sequence may result in a substance being insoluble in the solution that has some other solute already dissolved in it. Temperature is also a critical factor for the solubility of some substances, and thus, careful attention must be paid to preparation temperatures. When no indication of temperature is given by a formula, then it is assumed that room temperature water will be used. There are several other key points that should be stated. For example, whether a chemical is in its hydrated or anhydrous form is also very important since the concentration of a substance in solution may be significantly altered. Careful attention should be paid to the exact chemical in hand and weight adjustments should be calculated if necessary.

Example 1

To make a 1% solution of sodium carbonate, 1 gram of sodium carbonate (Na_2CO_3) is required in 100 mL of distilled water. However, if only sodium carbonate monohydrated ($Na_2CO_3{\cdot}H_2O$) is available, then **1.24** grams should be used to get a 1% solution.

Molecular Weight of sodium carbonate = 106.0 grams/mol

Molecular Weight of monohydrate = 124.0 grams/mol

Number of moles of sodium carbonate in a 1% solution:

$$1 \text{ gram}/106.0 \text{ grams/mol} = 0.010 \text{ mol}$$

Therefore, we need an equal number of moles for the monohydrate to get a 1% solution.

$$0.010 \text{ mol} \times 124.0 \text{ grams/mol} = 1.24 \text{ grams}$$

Solutions that are sensitive to aerial oxidation should be stored in labelled glass bottles, preferably in smaller quantities instead of in one large bottle so that less air space is present and deterioration of the solution is slowed. In addition, it is worthy to note that acids and bases should always be added slowly to large quantities of water to prevent the evolution of intense heat and splattering and should never be added the other way around.

Percentage solutions can be prepared in two ways: by weight (*w/v*) or by volume (*v/v*). Example 1 illustrates the preparation of a percentage solution by weight and Example 2 illustrates how a percentage solution is prepared by volume and also gives a formula for calculating such solutions.

Example 2

It is required that 100 mL of a 10% hydrochloric acid solution is prepared from existing concentrated hydrochloric acid.

The percentage of hydrochloric acid in the concentrated solution is approximately 37%.

Therefore, to calculate the volume of concentrated acid required:

$$\text{Percentage required} \times \frac{\text{Volume required}}{\text{Percentage available}}$$

$$10\% \times \frac{100\text{ mL}}{37\%} = 27\text{ mL}$$

Thus, to make the solution, 27 mL of concentrated acid (37%) is added to an initial 60 mL of distilled water in a volumetric flask and then the volume is brought up to the 100 mL mark on the flask with distilled water.

Finally, later in this manual it will be necessary to prepare saturated salt solutions (a solution that contains so much solute that no more can be dissolved in it and any excess of solute remains as a solid) so the preparation is now briefly outlined. First, it is recommended that you consult a chemical handbook to get an idea of the solubility of the particular salt. Begin the solution preparation by placing a small quantity of distilled water in a flask. It is important to start with a small quantity of water since the solubility of a substance may be very high and thus require an enormous amount of salt if larger volumes are used. The next step is to bring the water to the temperature at which the solution will be used since solubility is strongly affected by temperature. At this point, the salt is added until, after sufficient stirring, the solute remains undissolved at the bottom of the flask.

2.6.2 Laboratory Safety

Laboratory safety should be of primary concern to anyone who works with the hazardous materials used in photograph conservation and processing. It is the responsibility of everyone working in a laboratory to function in a manner that safeguards the well-being of fellow employees as well as their own. Many of the solvents and processing chemicals found in the Photograph Conservation Laboratory, studio, and darkroom are either caustic or toxic. Safety procedures and equipment must be in place to minimize the potential for accidents in these areas. Safety equipment must be carefully explained and demonstrated to students. Particularly important is the use of protective clothing such as lab coats, gloves, and safety glasses.

Instructors must show students the correct methods for handling and lawfully disposing of all chemicals. In Canada, this includes the correct labelling of all laboratory samples to comply with the Workplace Hazardous Materials Information System, abbreviated to WHMIS (WHMIS, 1988). Staff must also be trained to prepare them to handle injuries and administer first aid when appropriate. All accidents and injuries, regardless of how small or seemingly inconsequential, must be reported to the supervisor on duty.

We place particular emphasis on the danger of acid and solvent spills, which could occur in a darkroom or laboratory. In the event of a spill, students should follow the established procedures and then contact their instructor or supervisor. Clean up spills as soon as they occur using the acid or solvent clean-up kits. Any caustic or corrosive chemical that comes into contact with skin or clothing should be flushed immediately with plenty of running water and the affected clothing removed. For serious cases, emergency showers must be available and such cases must be followed up with medical attention.

The packaging of all photographic chemicals, solvents, and powders contains warnings about the toxicity of the material and prescribes appropriate first aid treatment. In addition, material safety data sheets (MSDS) for chemicals, which contain more detailed information, must be consulted before the chemicals are used. Virtually every step of photographic processing contains toxic or otherwise hazardous materials. Listed below are some of the more common sources (Shaw, 1983).

- developer agents and components
- organic chemicals and solvents
- acids
- alkalis
- metal compounds
- oxidizing agents
- gases
- pigments and dyes
- resins
- aerosol sprays

Even when some of the materials being used are not toxic, it is better to treat them all as poisonous. Clean up spills as soon as they occur. Keep hands well rinsed and away from your face. Never taste or directly smell any chemical. It is good practice to never lean on a lab bench, as unnoticed spills may be soaked up. It is better to work at arm's length from the experiment.

The Workplace Safety and Health Committee of the National Archives of Canada has been established to keep all employees informed of potential health hazards. They also identify and monitor any potentially hazardous situation in the workplace. A basic library of material relating to occupational hazards has been assembled by this committee and may be referred to when questions arise. Students should become familiar with the source books listed in the supplemental readings section.

Finally, students are expected to follow these basic safety rules:

1. Keep all work areas clean, well organized, and uncluttered. Eating, drinking, and smoking are prohibited in the laboratory.
2. When performing any experiment involving chemicals, students must wear a lab coat, protective safety glasses, and appropriate gloves. Respirators should be used where necessary. Long hair must be tied back and placed underneath the lab coat.
3. Observe all the precautions mentioned in each experiment and read the appropriate

material safety data sheets and instructions for all materials used in an experiment before beginning work.

4. Remember the location of all safety equipment such as clean-up kits, fire extinguishers, fire blankets, first aid stations, safety showers, eye-wash equipment, and the location of such things as emergency telephone numbers and the circuit breakers for the laboratory in use.
5. Know the correct procedure for responding to accidents and report them using the appropriate emergency telephone numbers.

2.7 Scientific Work Habits

2.7.1 Labelling Samples

Labelling is an integral part of proper scientific work habits. In a lab involved in work with chemicals and photographic samples, correct labelling of chemical solutions and photographic samples as to whether they are treated or untreated is an essential procedure that must be followed. Informative labels on bottles containing chemicals are necessary for successful experiments, laboratory safety, and facilitating their eventual lawful disposal. They also allow fellow workers to easily identify the contents of a specific bottle. With regard to the labelling of chemicals, there are two categories. First, there are chemicals from the manufacturer. These containers or bottles should carry appropriate labels that comply with WHMIS (in Canada) or legally required safety warnings along with various other chemical information on the product. If no date is provided on the label, the date on which the chemical arrived in the lab should be noted on the bottle, thus avoiding the use of old chemicals, which may have deteriorated. Second, there is the labelling of chemical solutions that have been prepared in the lab. These are usually stored in glass bottles and should have appropriate WHMIS or safety information labels on them. In addition, we recommend that the following be clearly stated on the bottle:

1. The name of the solution.
2. The composition and concentration of the solution.
3. The name of the individual who prepared the solution.
4. The date that the solution was prepared.
5. The pH of the solution if it is aqueous.

Labelling of photographic samples is equally important for future referrals and correct identification of samples that have been produced. There are various methods that can be used efficiently. Information may be lightly written on the back of photographic prints with an HB pencil; a print may then be placed in a Mylar or cellulose triacetate sleeve. Alternatively, a number may be assigned to the print (written on the back with an HB pencil) and then the print put into one of the sleeves mentioned above. The necessary information is written or typed on a permanent adhesive label and stuck on the sleeve. If the sleeve and print become separated, the print can be easily identified by reference to the number on the sleeve. The information with the corresponding sample number should also be written in a notebook in case the sleeve is misplaced. Negative samples should be placed in the sleeves described above with the necessary information stuck on the sleeves with permanent adhesive labels. The negative and identifying sleeve must not become separated since no writing on the negative with an HB pencil is possible and other marking devices are not recommended. Identifying notches are acceptable on some samples.

The information that is placed on a sample or label is critical. The following are imperative:

1. The type of paper or film.
2. Any special processing conditions that may have been used such as toning, poor washing, or fixing, etc.
3. The experimental treatment that the sample may have undergone, such as bleach and redevelopment, aging conditions (and many others) or whether it was simply a control sample.
4. The date the experiment was performed.
5. The sample reference number.
6. Any toxic or reactive materials that the sample was exposed to, including warnings whenever the sample may release chemicals that may be deleterious to other photographic samples it may be stored with.
7. Any other pertinent data regarding the sample.

Following these procedures will minimize errors and confusion.

2.7.2 Lab Records and Reports

Every experiment must be clearly and completely recorded in a laboratory notebook. This must be done in such a way that anyone who is conversant with the subject of the experiment can easily understand precisely what was done and what the results were.

In order to achieve clarity in notebook reporting, especially over a long period of time, certain rules must be followed. All entries must be recorded in pen, not pencil. Any errors or incorrect entries must not be obliterated but instead a single line should be drawn through the error and the correction written in a different place. Never write over anything. Although writing one number over another to correct it may seem to produce clearly readable notes at the time, after a few days or weeks it may be difficult to determine which number was written on top of which.

Correctness and completeness are also extremely important in recording information in a laboratory notebook. Avoid the temptation to write down data as quickly as possible. Do not write 1 when you mean 1.00, for example. Record all the data including tentative data. If there are any questions about the data while the experiment is running, this must be noted as well. Recording this type of information may save you from having to redo the experiment.

The laboratory notebook must be a bound hard-cover book. The front cover and first page must contain the student's name, the beginning and ending dates of the work in the book, and a description of the general subject(s) the book covers. The next three or four pages of the book are reserved for a table of contents, which will include the dates, titles, and page numbers of each experiment.

Every page of the book must be numbered. It is good practice to record data on the right-hand pages and reserve the left-hand pages for drawings, rough notes, and calculations.

The following is a list of the eight sections of an experiment that must be recorded in the laboratory notebook. The first three parts must be completed before beginning the experiment.

1. *Title*

   Each new experiment is started on a new page with the correct date.

2. *Purpose*

   Describe the motive for doing the experiment and what its objectives are.

3. *Theory*

   Describe briefly the theory behind each experiment in sufficient detail to demonstrate your understanding of it.

4. *Instrumentation*

   Every device used during the experiment is recorded. Information should include the serial number of the device, if available, as well as the full model name.

5. *Experimental Procedure*

   Every step of the experiment is recorded in this section. The description of the work done must be thorough enough so that someone else could duplicate your work.

6. *Data and Observations*

   All the data and observations are written in this part exactly as they were observed. Do not interpret or try to explain anything here. Just record the data as it is observed. One way to facilitate this is to set up a table for the data in advance to be filled in during the experiment. If you do this and observe something that does not fit into the table, it must be noted elsewhere in this section.

7. *Computations*

   This section, which is not always required, is reserved for computations that may be required upon completion of the experiment. This section is not to be used for rough calculations, which should be recorded on the left-hand pages. The method of each calculation must be clearly described. The method for repetitive calculations need be described only once.

8. *Discussion and Conclusions*

   The results of the experiment are discussed in relation to the stated purpose and theory behind the experiment. They should also be discussed, where appropriate, in relation to published data or other accepted results. Conclusions should be clearly stated. Do not be ambiguous. Ways in which the experiment may be altered in order to improve the results can also be suggested.

Reports are required for most of the work in this guide. They should follow the format of the experiment, except that the theory part of the work should be expanded and much of the experimental section may be condensed.

2.8 References

ANSI. 1986. *Methods for Manual Processing of Black-and-White Photographic Films, Plates, and Papers*. ANSI PH4.29-1986. New York: American National Standards Institute.

Eastman Kodak. 1987. *Kodak Professional Black-and-White Films*. Kodak Publication, no. F-5. Rochester, N. Y.: Eastman Kodak.

Jacobson, Ralph C. 1978. *The Manual of Photography*. London: Focal Press Ltd.

Shaw, Susan. 1983. *Overexposure: Health Hazards in Photography*. Carmel, Calif.: Friends of Photography.

WHMIS. 1988. *WHMIS Core Material: A Resource Manual for the Application and Implementation of WHMIS*. Richmond, B.C.: Workers' Compensation Board of British Columbia.

2.9 Supplemental Readings

Mackison, Frank W., ed. 1978. *NIOSH/OSHA Pocket Guide to Chemical Hazards*. Cincinatti, Ohio: National Institute for Occupational Safety and Health.

McCann, Michael. 1979. *Artists Beware!* New York: Watson Guptill.

Stecher, Paul G., ed. 1968. *The Merck Index: An Encyclopedia of Chemicals and Drugs*. Rahway, New Jersey: Merck & Co.

Ice cone. Montmorency Falls, Quebec. 1876. Alexander Henderson.
Contemporary print from copy negative of original print. National Archives of Canada/PA-138521.

3 Light-Sensitive Materials: Theory, Structure, and Deterioration Mechanisms

3.1 Photographic Image Formation

3.1.1 Introduction

The earliest photographic technologies were all based on the effect of light on light-sensitive metal salts, the most commonly used today being the silver halides. The darkening effect of light on silver nitrate has been known from the early 18th century, but in 1777 Carl Wilhelm Scheele made the first scientific study of a silver salt. He blackened silver chloride by exposure to sunlight and then proved it had turned to metallic silver (Haist, 1979).

The darkening of silver salts such as silver chloride or silver bromide by light does in fact produce metallic silver and a halogen. In the case of silver bromide, this photolytic reaction has been written (Sturge, 1977):

$$AgBr + hv \longrightarrow Ag + {}^{1}/{}_{2}Br_2$$

where AgBr is the ionically bound silver bromide, h is the Planck constant, v is the frequency of light, Ag is metallic silver, and Br_2 is bromine.

Some of the earliest inventors of photography coated paper with solutions of silver chloride to produce a light-sensitive paper. After a lengthy exposure to light, these papers showed a crude image — usually of objects placed upon them during exposure. These images had to be viewed under low light levels as continued exposure to light would darken the unexposed silver salts and eventually ruin the image.

To make photography a useful technology, various techniques were tried to permanently "fix" the image, i.e., to remove unexposed and unwanted silver halides. In 1839 Herschel first used sodium thiosulfate to fix a photograph on paper. The sodium thiosulfate formed water-soluble compounds with the remaining unexposed silver salts, which were then washed out of the paper leaving intact the silver image.

Since then a remarkably wide variety of photographic processes using silver halides as the light-sensitive material have been invented and widely used. Knowledge of the physics and chemistry of these processes has grown concurrently. Of particular interest to conservators is the structure of photographs produced by the different processes. This chapter will focus only on some of the more well-known photographic processes and materials and their deterioration mechanisms.

3.1.2 Printing-Out and Developing-Out Emulsions

When light of sufficient energy strikes a silver halide crystal, an electron may be freed from a bromide ion in the silver halide lattice. In this way, an electron-hole pair is generated so that the positive hole and negative electron may move through the crystal. Without the influence of an electric field to keep them apart, it would be reasonable to expect that the oppositely charged electron and hole would recombine. Thus the effect of light on the crystal would simply be to make it photoconductive. However, the crystal structure is not a perfect one and it is this fact that makes silver halide grains so useful. Real, as opposed to ideal, silver halide crystals have interstitial silver ions that are mobile inside the crystal. They also have sites on the surface of the crystal that act as traps for electrons. According to one theory, when an electron-hole pair is generated, there is a good probability that the electron will become trapped at the surface of the crystal and that subsequently an interstitial silver ion will be attracted to it. On reaching the trapped electron, the silver ion is neutralized and remains on the surface of the crystal. The site that now contains a neutral silver atom is still a trap for electrons and continues to attract other photogenerated electrons that in turn attract other silver ions to form a speck of silver metal.

Similar silver metal sites may be produced inside the crystal but the probability of this occurring is much smaller. At the same time, the holes are believed to migrate to the surface of the crystal where they neutralize a halogen ion. In the case of silver gelatin systems, the resulting halogen is then adsorbed to the surrounding gelatin.

Provided that at least four silver atoms are generated at one site, the resulting speck of silver is quite stable. These and larger silver metal sites are referred to as latent image specks. It is in fact the silver halide grains that contain these surface silver specks that form the latent image which may be chemically developed later into a visible image. If the silver grain receives a great deal of light exposure, silver specks will appear both on the surface of the crystal and inside the crystal. With sufficient exposure and efficient removal of the resulting halogen, enough silver metal will be produced to make an image visible without further chemical development. The light required to do this is much greater than that required to produce a latent image. The initial sensitized papers invented in the 1830s and 1840s required exposure to direct sunlight for roughly 10 minutes or more.

Photographic materials that have been designed to produce visible images by exposure to light only are called *printing-out papers* (POP) and include albumen papers, salted paper prints, and silver gelatin papers. Although printing-out papers constitute the majority of 19th-century photographic prints, there is at least one silver gelatin POP paper still being manufactured.

Printing-out papers are usually warm-tone materials and have very small silver grains, on the order of 10 to 100 times smaller than the silver found in modern photographic papers.

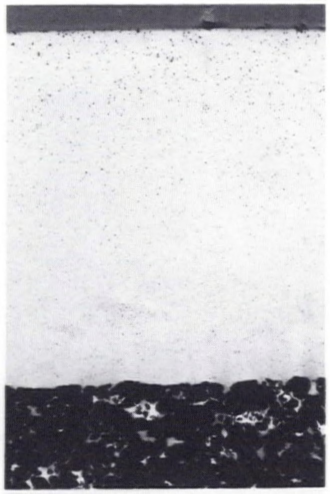


Fig. 3.1: Cross-section of a contemporary POP paper (Kodak Studio Proof) magnified 3,700 times. The gelatin layer is sandwiched between a dark layer at the bottom, which is the baryta layer, and a grey layer at the top, which is the embedding medium used to prepare the sample.

Fig. 3.2: Cross-section of a contemporary DOP paper (Kodak Kodabromide Grade 4) magnified 3,700 times. The gelatin layer is sandwiched between a layer of dark particles at the bottom, which is the baryta layer, and a grey layer at the top, which is the embedding medium used to prepare the sample. A clear silver-free zone below this grey layer is a gelatin supercoat that serves as protection against abrasion.

Following their exposure to light, most contemporary silver halide emulsions require further chemical treatments to produce elemental silver to form the visible image. In the case of papers, these are known as *developing-out papers* (DOP).

Developing-out materials, whether papers or films, require the introduction of a developing agent, which continues the process of producing metallic silver. It does this by providing the necessary electrons to continue the actual, as opposed to latent, image formation. At or near the latent image speck, the electrons donated from the developing agent molecules eventually combine with adjacent silver ions to form more metallic silver. Only after a million or more silver atoms are formed does the latent image become visible and therefore of practical use.

Fig. 3.3: Filamentary silver from a contemporary DOP paper (Kodak Ektalure Paper) magnified 16,000 times.

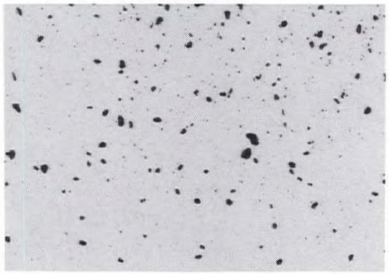


Fig. 3.4: Non-filamentary silver particles from a POP paper magnified 16,000 times.

3.1.3 Chemical and Physical Development

The size of the elemental (metallic) silver grains as well as their shape, and the tone of the resulting image, are all strongly dependent on the size and shape of the original silver halide crystals and the type of development employed. *Chemical development* is said to occur when the silver ions of the exposed silver halide crystal itself are reduced to metallic silver. *Physical development* is said to occur when the latent image is amplified by using silver ions that are part of the developer solution. Modern physical developers no longer contain silver ions, but rather contain substances that make soluble silver ions from the unexposed silver halide grains of the photographic emulsion itself. These silver ions are eventually redeposited on the latent image in the form of metallic silver. Both chemical and physical developers are currently available.

3.1.4 Filamentary Silver Formation

When silver halide crystals are developed using chemical development, metallic filamentary silver is formed. Silver grains can have densely packed filaments or fine, open configurations, depending in part on the compressive forces that the gelatin exerts on the filaments. This compression is affected, in turn, by the processing temperature, the degree of softness of the gelatin, and the type of developing solution used. Highly solvent developing solutions and physical developers that contain silver salts result in "clumps of closely packed particles of metallic silver, but no filaments of silver" (Haist, 1979). Generally speaking, chemical developers result in filaments, and physical developers produce compact grains. Some developers that contain a moderate amount of a silver halide solvent, such as sodium sulfite, will result in a more compact grain than would be produced by pure chemical development.

3.1.5 Image Tone

Image tone is dependent to a certain degree on the tone of the support paper and baryta layer, and the degree of "fog," a property we will discuss later in this guide (see Section 4.2). In addition, the tone of the final photograph can be manipulated by the use of a toner as an after-treatment. In the case of developing-out papers, the choice of developer and dilution affects the image tone. Among all the variables that contribute to it, the property we call "tone" is largely dependent on the light-scattering and absorbing properties of particular kinds of image silver, particularly by the grain and filament structure. Basically, more finely divided filamentary silver grains produce images of warmer tones such as yellow, brown, or olive. Coarser grain materials (those consisting of "clumps" of closely packed filaments of metallic silver) yield colder blue to neutral black image tones. Printing-out papers (albumen, salted paper prints, and silver gelatin prints), which characteristically have very small silver grains, yield warm tones. Developing-out papers generally yield colder tones.

Between the general terms of "warm" and "cold" tone images, there are no clear dividing lines. The variables introduced by the kind of paper, the type of silver halide used in the emulsion, the dilution and kind of developer used, and subsequent processing and after-treatments can all affect image tone.

3.1.6 Paper and Film Speed

The relative sensitivity to light, or the "speed" of photographic materials, is also dependent on the size and shape of the light-sensitive silver halide crystals. Films are generally "faster" (more sensitive to light) than papers, because their ability, when used in a camera, to stop action in a scene or to permit the use of small apertures to allow reasonable depth of field is so important. Paper speed is relatively unimportant; indeed, darkroom work often requires time to adjust the exposure in various parts of the enlarged or contact-printed negative, a process called "burning-in"and "dodging." The relatively "fast" speed of film comes at the expense of grain size: the faster the film, the grainier the resulting negative image; the slower the film, the finer the resulting image. Any graininess that is apparent on the resulting paper print has been contributed by the negative, not the photographic paper. Paper, being relatively slow in speed, has an extremely fine grain structure.

3.2 Structure of Photographic Materials

3.2.1 Introduction

Most photographs are complex multi-layered materials. They generally consist of some or all of four main components:

1. Support or base,
2. Interlayer,
3. Binding medium,
4. Image-forming substance.

Some photographs, like platinum prints, salted paper prints, and daguerreotypes, employ no binding medium or interlayer. In the case of platinum and salted paper prints, the metal salts are embedded directly in the paper fibres of the support material. The daguerreotype image consists of microscopic particles of silver amalgam on a layer of silver that is coated on a copper plate. The layer structure of most photographic images consisting of a support and a binding medium of different properties can be demonstrated by the behavior of these images towards changes in the surrounding relative humidity. We describe this in more detail in Chapter 9, Section 9.2.1.2.

Various materials have been used as components throughout the history of photography:

Support

The following are rather common:

- paper
- flexible films:
  - cellulose nitrate
  - cellulose diacetate and mixed cellulose esters
  - cellulose triacetate
  - polyester
- glass

Rare are:

- metal
- ivory
- wood
- leather
- cloth

Binding Medium

- gelatin (most common)
- albumen
- collodion
- starch (rare)

Interlayer

In paper prints:

- baryta (barium sulfate)
- pigmented polyethylene (in RC-papers)

In films:

- subbing layers (e.g., cellulose nitrate)

Image-Forming Substance

- silver (most common)
- other metals:
    - silver amalgam (in daguerreotypes)
    - iron
    - platinum
    - palladium
- metal salts
- carbon
- other pigments
- dyes

By far the most widely used photographic materials today employ silver halides as precursors of the image-forming substance and gelatin as the binder. The resulting silver gelatin negatives and prints are also found in the greatest numbers in historical collections.

Although the selection of the support material depends on the intended purpose of the photograph (i.e., glass and plastic film for negatives and transparencies, paper for reflection prints), gelatin is the material of choice as a binding agent for contemporary photographs in black-and-white and color. There are numerous reasons for its wide acceptance. It has unique properties that permit the aqueous processing of previously dry emulsions; and it facilitates manufacturing of sensitive emulsions. Gelatin also gives good protection of the silver halides and, later, the processed silver grains when it is dry. Gelatin readily takes up water and at high enough temperatures melts and forms a sol with water. Silver halide crystals may be grown within a gelatin melt. The gelatin keeps the crystals suspended and prevents coagulation of the silver halide grains as they grow. If the warm gelatin is not diluted beyond a 1% solution, it may be cast onto a support and dried where it will form a semi-solid layer with good mechanical strength.

Such a layer of gelatin is still capable of again taking up large quantities of water and the various processing chemicals dissolved in it. The ability of gelatin to repeatedly swell and de-swell when soaked with water and dried again is what makes post-exposure processing of photographic materials possible. Gelatin has other advantages as a binder as well:

1. In the early years, some constituents of gelatin helped to increase the sensitivity of the silver grains.
2. The physical properties of a coated layer may be altered by later treatments, including hardening.
3. Gelatin helps to stabilize the latent image by accepting halogens released as part of the latent image formation process.
4. It plays a role in insulating unexposed grains from the effect of developers during development.
5. It is transparent, grainless, and virtually colorless.
6. It is derived from animal collagen and so is not difficult to obtain and does not readily deteriorate.

3.2.2 Structure of Contemporary Film

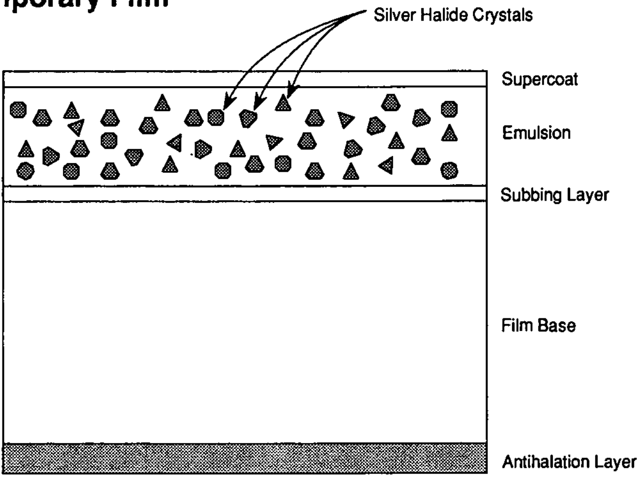


Fig. 3.5: Schematic cross-section of unexposed and unprocessed contemporary film (not drawn to scale).

Figure 3.5 illustrates the structure of a typical black-and-white photographic film. In an actual cross-section that shows the entire structure, the grains would be small specks, not the large crystal shapes illustrated here and the base would be much larger than illustrated. From top to bottom the layers of the film are:

A. *Gelatin Supercoat*: This is a protective layer of gelatin. Silver grains are sensitive to light, but also to abrasion. Without this layer, any abrasion received during manufacture or handling of the unexposed film would show up after development as black abrasion marks.

B. *Emulsion*: The silver gelatin emulsion consists of the gelatin binding medium and the light-sensitive silver halide crystals and may be made up of several layers, depending on the characteristics of the film type. (In some modern black-and-white films, the emulsions may contain layers of black-and-white chromogenic dyes.)

C. *Subbing (Substratum) Layer*: A binding layer on a photographic support to provide better adhesion between the emulsion and the base.

D. *Support/Film Base*: Most contemporary roll films use cellulose triacetate as the support. Unlike the early plastic bases (including cellulose nitrate and cellulose diacetate), cellulose triacetate is very stable chemically and dimensionally. Most modern sheet films

3.2.3 Structure of Contemporary Fibre-Base Paper

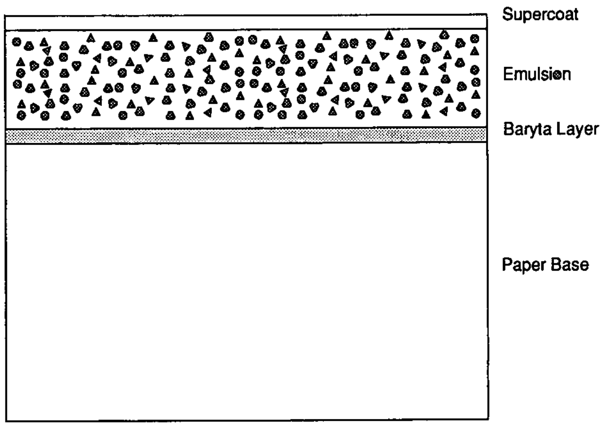


Fig. 3.6: Schematic cross-section of unexposed and unprocessed contemporary fibre-base paper (not drawn to scale).

have a polyester base for even greater dimensional stability. These modern bases are transparent, grainless, and virtually colorless.

E. *Gelatin Anti-Curl, Anti-Halation Layer*: This layer is designed to match the thickness of the emulsion plus supercoat, to counteract the effect of humidity on the emulsion layer that may cause contraction and expansion. This layer usually contains an anti-halation dye, designed to absorb light when the film is exposed. Without it, light passing through the emulsion can be reflected back to the emulsion, forming "halos" — unwanted secondary exposure caused by stray light — around image highlights.

Figure 3.6 illustrates the structure of typical black-and-white photographic paper. In an actual cross-section, the grains would be tiny specks, many times smaller than the grains in the film emulsions. The base would be much larger than illustrated. From top to bottom, the layers of the paper are:

A. *Gelatin Supercoat*: This is a protective layer of gelatin. Silver grains are sensitive to light, but also to abrasion. As with film materials, without this layer, any abrasion received during manufacture or handling would show up after development as black abrasion marks.

B. *Emulsion*: This consists of silver halide crystals suspended in gelatin. Depending on the image tone and contrast desired, the light-sensitive halide crystals may be silver bromide (the most common) or silver chloride or various combinations of these salts with or without silver iodide.

C. *Baryta Layer*: This is a layer of barium sulfate in gelatin, which separates the paper base from the emulsion. It is an opaque white layer serving three functions:

   1. It increases the whiteness or reflectance of the base, extending the tonal range of the highlights.
   2. It acts as an inert seal between the emulsion and any impurities in the paper and conversely protects the paper from absorbing too many processing chemicals.
   3. It provides a flatter, smoother, more compact surface on which to coat the emulsion.

D. *Support/Paper Base*: Photographic papers are strong and nearly chemically pure, devoid of any elements that may interact with the silver halides in the emulsions. The major manufacturers of photographic paper make their own paper base. This self-manufactured paper has a high degree of purity and permanence. Commercially prepared silver gelatin papers are available in various thicknesses or weights. Due to the fibrous nature of paper, an anti-curl backing layer is generally unnecessary under normal processing conditions.

3.2.4 Structure of Resin-Coated Paper

Figure 3.7 illustrates the structure of a typical black-and-white resin-coated photographic paper. In an actual cross-section, the grains would have a similar size to those in the purely fibre-base paper in Figure 3.6. The base would be much larger than illustrated. From top to bottom, the layers of the paper are:

A. *Gelatin Supercoat*: This protective layer of gelatin protects the emulsion from abrasions that can produce black marks during development.

B. *Emulsion*: This contains the image-forming substance, silver halide crystals, in a binder of gelatin. It is essentially the same emulsion found on film and fibre-base papers. As with fibre-base papers, various silver halides — bromide, chloride, iodide — may be used singly or in combination, to offer various image tones and contrast grades.

C. *Polyethylene (Resin-Coating)*: This is a layer of polyethylene pigmented with titanium dioxide (TiO_2), which replaces the traditional baryta layer and seals the paper base from water and prevents absorption of processing chemicals in solution.

D. *Support/Paper Base*: The paper base is made from highly purified wood pulp with the lignin removed.

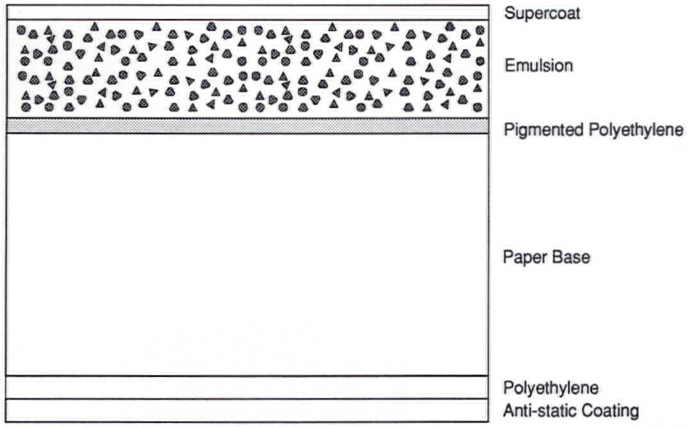


Fig. 3.7: Schematic cross-section of unexposed and unprocessed resin-coated paper (not drawn to scale).

E. *Polyethylene Coating*: This layer seals the back side of the paper against water and chemical absorption. It also acts as an anti-curl layer. Because of their "sealed" construction, resin-coated papers may be processed very rapidly, will dry completely flat in a relatively short period of time, and are dimensionally stable.

F. *Anti-Static Coating*: This coating reduces the build-up of static electric charges in the polyethylene.

3.3 Mechanisms of Deterioration

3.3.1 Introduction

This section presents some notes on the stability of photographic records and the more common patterns of their deterioration. Empirical observation has shown that the majority of photographic images in collections is in relatively good condition. This is especially true for silver gelatin materials made by a highly developed manufacturing industry to precise specifications. Photographic manufacturing requires strict quality control measures and has been backed up by extensive research since the beginning of this century. Judged solely from the point of view of the photograph conservator, who often sees by the very nature of his or her work the most deteriorated objects, photographs appear to be weak, fragile, and prone to deterioration. However, since it is only a fraction of the pictures in a collection that is selected for conservation treatment, the impression of their instability is deceiving. Photographs that have suffered damage have often been made by historical, now obsolete, processes. In some cases, such images were made of inherently unstable materials that may lead to some form of image degradation. Prominent examples of such materials are cellulose nitrate film base, which is not permanent and cannot be made so, or the yellowing of the highlights in albumen prints. The vast majority of photographic images has exhibited a high degree of permanence, which will assure their survival for many years. They may suffer, however, as a consequence of external factors that are discussed on the following pages.

Deterioration of photographic materials is principally caused by either some mechanical process or chemical reactions. The term mechanical process describes the consequences of careless handling and physical abuse when viewing, studying, copying, printing, or exhibiting photographs. Chemical reactions may occur in all components of a photograph, usually in the presence of chemically reactive substances, but take place predominantly, and most visibly, with the image-forming substance. In rare instances, chemical reactions may also be triggered by certain components of a photograph themselves. Other causes of deterioration, such as those of a biological nature, are minor in comparison with the two processes noted above. Damage of a mechanical nature occurs largely to the support (e.g., a torn print may result, or a broken glass plate) and to the image layer as abrasion. Destructive chemical reactions, on the other hand, affect mainly the image-forming substance, giving rise to fading (loss of density), discoloration, or staining (increase in density). Staining in black-and-white photographs may occur in highlight areas as a consequence of the presence of residual processing chemicals. In color photographs, the occurrence of stains is also

Fig. 3.8: A reproduction of a color print on Kodacolor paper, dating from the 1950s, which shows coupler print-out.

generally visible in low density areas where it is caused by the effect of heat. If staining is caused by light, the term print-out is used to describe that effect. A well-known example is the appearance of an overall yellow-red cast on early Kodacolor prints, which is produced by the print-out of residual dye couplers in the image layer (Heidke et al., 1985).

Staining in both black-and-white and color photographs can also originate from an outside source, for example by the transfer of reactive substances from a filing enclosure to the photograph. Certain chemicals, rarely found in normal environments where photographs are kept, affect the binding medium.

Interest in prolonging the life of photographic images has initiated a search for solutions to two general concerns:

1. Effective procedures for the repair and restoration of mechanical damage suffered by prints or negatives, and for the selection of materials that are suitable to be used in such work.
2. Methods for delaying and possibly reversing the chemical deterioration of the silver image.

Such methods and procedures will be presented in the form of experiments throughout this guide. Practical experiments begin in Chapter 4. Following are some notes on typical deterioration patterns for the major components of a photograph.

3.3.2 Notes on the Stability of Support Materials and Binding Media

Fig. 3.9: An albumen print mounted in an album page, which exhibits brown spots known as foxing. There is no appearance of foxing on the albumen print.

Paper

Photographic paper is, judged from experience, among the most permanent papers ever made. Manufacture of papers specifically for photographic purposes began in the mid-1860s. It became clear early on that such papers had to be free of metal particles, sulfur-containing compounds, and sizes that could affect either the photographic properties of the raw stock or the stability of the processed image. Figure 3.9 illustrates this observation: an albumen print mounted in an album page.

Although the album page shows evidence of foxing — the development of brown, feathery spots linked to the presence of microorganisms and traces of iron — the photographic paper print remains free of any blemishes.

Damage to paper prints happens most often through handling and use. The result may be a torn print, a folded-over corner or even a piece missing from a print. A single example of a photographic print that became brittle comes to mind: one that was kept in the same envelope with a disintegrating cellulose nitrate negative.

Exceptions to the foregoing are the earliest paper prints dating from the first 25 years or so of photography. Requirements for these are reported as "good quality writing paper," but what this meant precisely is not explained. In the interest of preserving early paper prints, which are milestones in the development of photography, it is advisable to consider them to be much more fragile and sensitive to the effects of aggressive chemicals than industrial photographic papers.

Plastic Film Bases

The film bases currently in use consist either of cellulose triacetate or polyester [poly (ethylene-terephthalate)]. The stability of both these materials is widely accepted and confirmed. Current polyester films are chemically inert and have good dimensional stability. Cellulose triacetate films are expected to retain acceptable physical properties for at least 300 years if kept under recommended storage conditions, i.e., 21°C and 50% RH (Adelstein and McCrea, 1981). Hydrolysis of cellulose triacetate films should not occur unless stored under the most unfavorable environmental conditions.

The foregoing film bases were preceded by materials such as cellulose diacetate, acetate propionate, and acetate butyrate. Some of these early cellulose acetate films suffer from permanent shrinkage. Figure 3.10 shows an example of a sheet film negative with a shrunken film base and a wrinkled gelatin layer on top of it. Such shrinkage has been explained by the loss of residual solvent or other volatile material, such as plasticizer; by the plastic flow of the base; and by release of strain or recovery from deformation (Calhoun, 1944).

Fig. 3.10: Sample showing the effects of a shrunken film base on the gelatin layer.

Of the older materials, cellulose nitrate is known to be inherently unstable. It is highly flammable and may, under unfavorable storage conditions, ignite spontaneously. Such an event has rarely occurred in collections of still photographic negatives. Most reports of burning cellulose nitrate films describe fires in motion picture film exchanges (Cummings, Hutton and Silfin, 1950). One exception is a fire of processed radiographic films in 1929 in a clinic in Cleveland, Ohio. The inherent instability of cellulose nitrate film manifests itself in a slow degradation during which reactive gaseous chemical compounds are released. The aggressive compounds may now affect other photographic records stored nearby. The process was described by Carroll and Calhoun in 1955. An authoritative paper on the storage of still photographic cellulose nitrate negatives was published by Calhoun in 1953.

Glass Plates

The chemical and dimensional stability of glass plates is excellent. Their major drawbacks as photographic supports are their weight and brittleness. Unless glass plates are broken, particularly during transport, their preservation does not pose many problems.

Binding Media

Of the three most common binding media found throughout the history of photography, gelatin has been used almost exclusively for the past 100 years. If gelatin layers are kept dry in normal room conditions, their stability is equivalent to that of cellulose triacetate film base. Gelatin becomes vulnerable, however, in a wet state, when its stability depends to a large degree upon the pH of the solution into which it is submerged. Its resistance to processing solutions that have different pH values can be increased through the use of hardeners. Common hardeners contain bivalent metal ions such as those present in aluminium and chromium salts. Formaldehyde and other aldehyde derivatives are also often used as hardeners. Hardeners reduce the swelling of gelatin

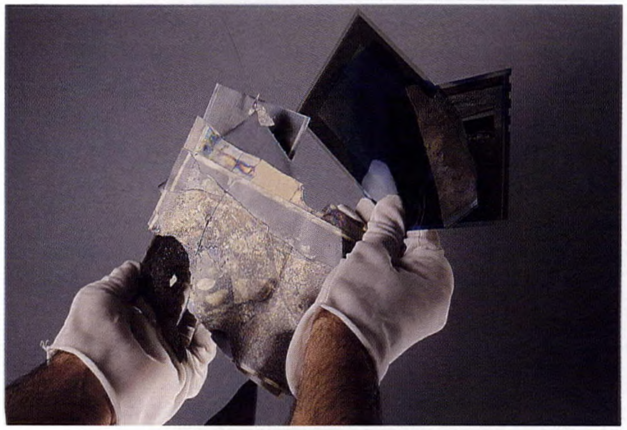


Fig. 3.11: Negatives on a deteriorated cellulose nitrate film base.

layers in aqueous solutions and increase the so-called melting point, which is defined as the temperature at which the layer breaks up, in a specified alkaline salt solution. The student will find in Chapter 10 some experiments on testing the properties of gelatin layers.

The binding medium in albumen prints has demonstrated good physical stability, witness the many photographs made in the 19th century by this printing-out process that are preserved in collections today. Naturally aged albumen layers develop a network of fine hairline cracks on the surface, a feature that can actually serve as an aid to the identification of albumen prints. Figure 3.12 is a micrograph of the surface of an albumen print that shows the presence of numerous small cracks. A further distinguishing feature of 19th-century albumen prints is the color of the highlights. In the sensitization step, albumen papers, coated with a layer of egg white that contains sodium chloride, are floated on a silver nitrate bath. The purpose of this step is the formation of the light-sensitive substance silver chloride in the albumen layer. In a side reaction, the silver nitrate also acts as a hardener on the albumen layer by forming chemical bonds with amino acid components of the albumen. These complex silver compounds remain in the image layer. Over long periods of time they will print out, particularly when exposed to light, with the concurrent formation of yellow compounds. This reaction is not particularly noticeable in medium and high density areas, but in the lighter areas it is quite apparent. It explains why the highlights in historical albumen prints are never pure white, but always a yellowish color.

Fig. 3.12: A photomicrograph showing the presence of numerous small cracks in the albumen layer of a print.

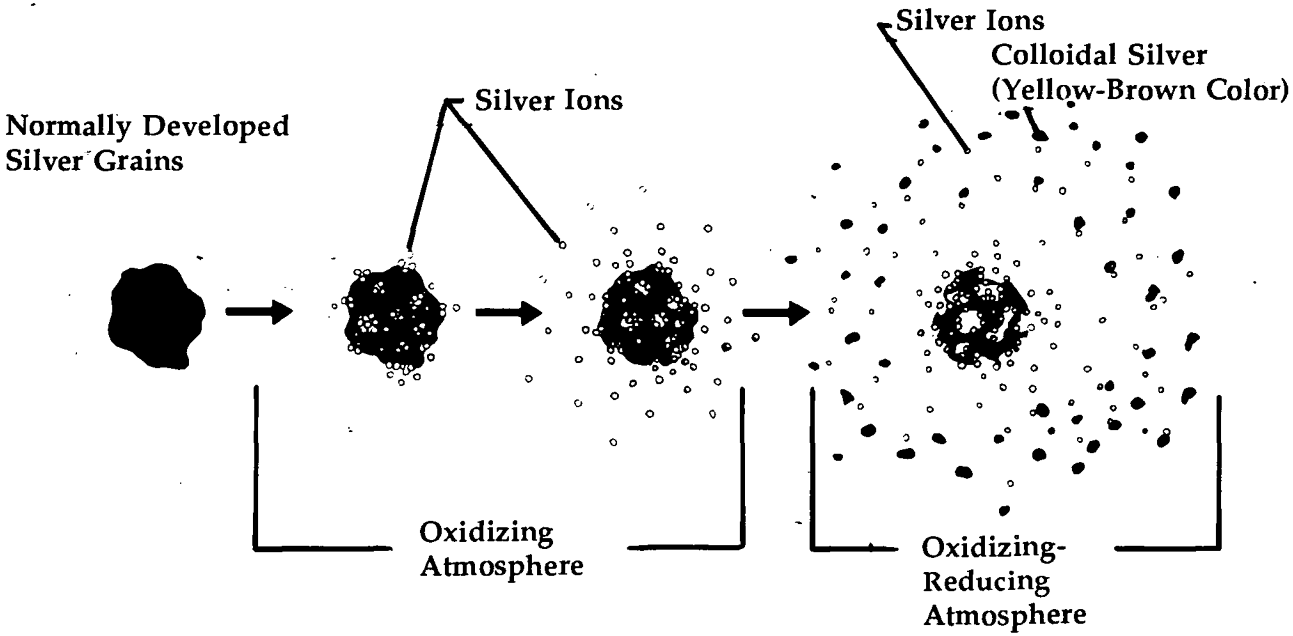
Glass plate negatives made by the wet collodion process have survived well because of a protective varnish layer applied to their surface. Likewise, the image layer in collodio-chloride prints has demonstrated its good stability throughout the years, giving rise to few concerns. Collodion layers are susceptible to water damage. Collodion photographs that have accidentally been soaked in water cannot be frozen and freeze-dried, but must be dried in open air.

3.3.3 Stability of Image-Forming Substances

Photographic images may suffer for two broadly defined reasons, as noted: the results of use and handling of photographs, and the effects of chemical reactions with aggressive substances which may occur during storage or display. All other causes of deterioration pale in comparison with these two. The reactive materials necessary to cause chemical changes may originate either from the environment or from the photograph itself in the form of residual processing chemicals or of degradation products from inherently unstable components of the image. Such chemical reactions frequently take place with the image-forming substance as a reaction partner, and so may lead to fading or discoloration of the image. Chemical degradation in black-and-white photographs is produced primarily by substances that oxidize the image silver. Examples of such substances are hydrogen peroxide, nitrogen oxides, thiourea, and others. The image discoloration caused by residual processing compounds, discussed in the photographic literature throughout the history of the medium, is but a special case of the oxidation of image silver. Procedures for the correct handling and use of photographs are outlined in Chapter 9, but the mechanism of image silver deterioration through the action of oxidizing chemicals merits further elaboration.

The fading of black-and-white photographic prints was investigated within a few years of the invention of photography by a committee founded for that purpose in London, England. In a first report, published in 1855, the committee noted that hydrogen sulfide in the presence of moisture could result in discoloration and fading of paper prints (Delamotte, 1855). The committee also found that the presence of residual sodium thiosulfate, the main component of fixing baths, led to similar destructive actions on photographs. A photographer in India, J.S. Gladstone, reported about 40 years later that high atmospheric humidity was responsible for the fading of photographs, because the moisture acted as "the instigator of a chemical action in the material of the paper," during the course of which "the image silver is converted into a compound that diffuses and disappears in the support"(Gladstone, 1892). Here we notice two significant observations: the formation of silver compounds, and the ability of these compounds to migrate away from the original site of the silver grains. In all cases the presence of a strong oxidizing agent is necessary to bring about image discoloration, a reaction that is accelerated by moisture. In Chapter 10, we will describe some experiments that demonstrate the reaction of photographic prints when exposed to oxidizing atmospheres.

Since the 1970s, a number of authors have published data indicating which materials or compounds could be shown to produce discoloration in black-and-white photographs. In 1984, researchers of the Fuji Photo Film Co., Ltd. published a schematic representation of the oxidation of image silver and the subsequent migration of silver ions away from the image silver grains (Torigoe et al., 1984). This reaction scheme is shown in Figure 3.13.



Developed Silver Grains

Formation of Silver Ions from Developed Silver Grains

Silver Ions Migrating from Developed Silver Grains and Dispersion

Silver Ions Reduced During Dispersion ---> Formation of Silver Atoms ---> Receding Ions Recombine in the Silver Atoms ---> Reduction ---> Formation of Colloidal Silver

Fig. 3.13: Schematic representation of oxidative degradation of developed silver followed by the formation of fine silver particles according to Torigoe et al.

Fig. 3.14: Transmission electron micrograph showing degraded silver grains from a discolored 50-year-old print at a magnification of 35,300 times.

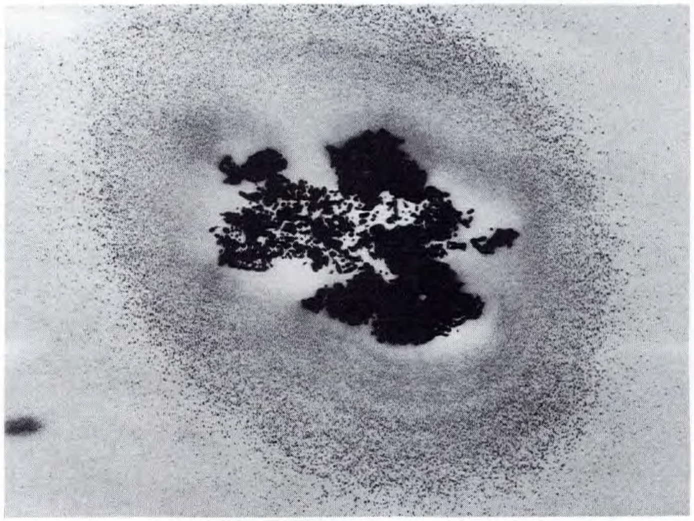


Fig. 3.15: Transmission electron micrograph showing a degraded silver grain from a naturally aged black-and-white negative on film. The magnification is approximately 26,700 times.

Although it is reasonable to assume that this schematic representation was based on an examination with a transmission electron microscope (TEM), Torigoe and his colleagues did not actually publish an electron micrograph of the silver ion migration. Figure 3.14 shows an electron micrograph of a degraded silver grain from an approximately 50-year-old print, and Figure 3.15 shows a similar event from a naturally aged black-and-white negative (Hendriks, 1988; Hendriks and Ross, 1988; Hendriks, 1989). This gradual destruction of the physical integrity of processed silver grains adds new challenges regarding the restoration of such images in chemical solutions.

The migration of silver ions away from processed silver grains that are exposed to an oxidizing atmosphere can be demonstrated in laboratory experiments. A print made on a contemporary contact speed developing-out paper is exposed at 50°C in a desiccator to a hydrogen peroxide atmosphere for about three days. A cross-section is then prepared and the sample is studied in the TEM. Figure 3.16 shows silver grains

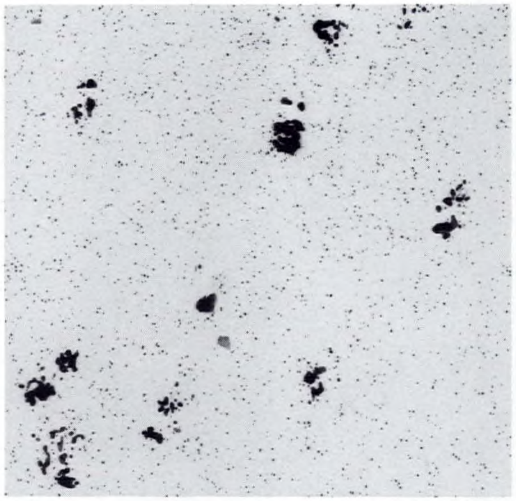


Fig. 3.16: Transmission electron micrograph illustrating the effects of a peroxide treatment on a contemporary developed-out paper at a magnification of 33,300 times.

from a print so treated. By varying the relative humidity, it is possible to determine its effect on the rate of the migration reaction. For example, experiments carried out at relative humidities of 30%, 75%, and 95%, clearly showed the oxidation and migration to proceed at a faster rate at higher relative humidities. By varying the parameters of this reaction, the factors that determine the degree to which the reaction can proceed can be identified. Similarly, the use of different oxidizing agents, such as hydrogen peroxide or thiourea, permits studying the resulting differences in the structure of the degraded image silver.

The fate of the silver ions once they have migrated away from their parent grains is not entirely clear. If suitable anions are available, the formation of stable silver salts is the preferred reaction (Henn and Crabtree, 1947). Otherwise, the formation of colloidal silver is the alternative. A distinction between the two reaction products cannot be made by electron microscopy alone. An analytical technique known as Energy-Dispersive X-Ray (EDX) analysis is capable of detecting small amounts of metals and sulfur present in a system. If an analysis shows silver to be present along with sulfur, it is reasonable to assume the formation of silver sulfide, a stable and insoluble compound. If it is possible to convert silver sulfide, and other silver salts that may be present in a photographic emulsion as a result of chemical degradation, back to elemental silver, such a reaction would constitute a restoration of the faded image. Experiments demonstrating this process are described in Chapter 8.

The image in color photographs is formed of organic dyes. Their stability, when kept in equivalent conditions, is generally inferior to that of black-and-white silver images. Changes in the stability of color photographs vary, depending on whether storage conditions are under light or in the dark. Different fading mechanisms operate under the two conditions. The terms *dark storage* and *dark storage conditions* originate in reference to color photographic materials. Dyes in color photographs are probably the only materials in a visual art medium to fade appreciably in the dark. Since the temperature level during storage is the factor determining dark fading, storage at low temperature has been proposed and is actually in use in several photograph and film collections. The fading upon exposure to light of color photographs can easily be avoided in storage. It becomes a question of concern when color photographs are to be displayed. The subject is discussed in Chapter 9.

The destruction of dyes in color photographs can occur by several mechanisms. Common among them are hydrolysis of a dye, its oxidation or reduction. Since the destruction of color photographic dyes is considered to be irreversible, at this time chemical restoration does not seem to be possible. Because of this, we do not present a detailed discussion of the chemical mechanism of dye fading, but refer the student to the extensive literature (see for example, Vittum and Weissberger, 1954; Sano, 1969; Tuite, 1979; and Bard et al., 1980).

The stability of image-forming substances in photographs other than those containing elemental silver or organic dyes is less well known. An exception is elementary carbon, the substance used in Woodburytypes and carbon prints. It is chemically inert and fade resistant in light. The permanence of these photographs is determined by the stability of the gelatin layer. Precise data on pictures made by other non-silver processes have not been published. Much experience and knowledge about the materials need to be accumulated.

3.4 References

Adelstein, P.Z., and J.L. McCrea. 1981. Stability of Processed Polyester Base Photographic Films. *Journal of Applied Photographic Engineering* **7**(6): 160-167.

Bard, C.C., et al. 1980. Predicting Long-Term Dark Storage Dye Stability Characteristics of Color Photographic Products from Short-Term Tests. *Journal of Applied Photographic Engineering* **6**(2): 42-45.

Calhoun, J.M. 1944. The Physical Properties and Dimensional Behaviour of Motion Picture Film. *Journal of the Society of Motion Picture Engineering* **43**(4): 227-266.

Calhoun, J.M. 1953. Storage of Nitrate Amateur Still-Camera Film Negatives. *Journal of the Biological Photographic Association* **21**(3): 1-13.

Carroll, J.F., and J.M. Calhoun. 1955. Effect of Nitrogen Oxide Gases on Processed Acetate Film. *Journal of the Society of Motion Picture Engineers* **64**: 501-507.

Cummings, J.W., et al. 1950. Spontaneous Ignition of Decomposing Cellulose Nitrate Film. *Journal of the Society of Motion Picture Engineers* **54**(3): 268-274.

Delamotte, P.H., et al. 1855. Fading of Positive Photographic Pictures on Paper. *Journal of the Photographic Society (London)* **2**(36): 251-252.

Gladstone, J.S. 1892. Fugacity of Bromide Prints. *British Journal of Photography*, July 29, 484.

Haist, Grant. 1979. *Modern Photographic Processing.* 2 vols. New York: John Wiley & Sons, 1:11-139, 713, 717.

Heidke, R.L., et al. 1985. Evolution of Kodak Photographic Color Negative Print Papers. *Journal of Imaging Technology* **11**(3): 93-97.

Hendriks, Klaus B. 1988. Über die chemische Restaurierung des Silberbildes vergilbter oder verfärber Photographien [On the Chemical Restoration of Silver Images in Faded or Discolored Photographs]. *Wiener Berichte über Naturwissenschaft in der Kunst* **4/5**: 372-389.

Hendriks, Klaus B., and Lincoln Ross. 1988. The Restoration of Discolored Black-and-White Photographic Images in Chemical Solutions. In *American Institute for Conservation of Historic and Artistic Works Preprints of Papers Presented at the Sixteenth Annual Meeting, New Orleans, 1-5, June, 1988,* 99-117. Washington, D.C.: AIC.

Hendriks, Klaus B. 1989. The Stability and Preservation of Recorded Images. In *Imaging Processes and Materials: Neblette's Eighth Edition.* Ed. John Sturge, et al. 637-684. New York: Van Nostrand Reinhold.

Henn, R.W., and J.I. Crabtree. 1947. Sulfide Stains: Its Nature, Cause, and Methods of Preservation. *Photographic Society of America Journal* **13**: 752-758.

Sano, K. 1969. The Alkaline Hydrolysis of Yellow Azomethine Dyes. *Journal of Organic Chemistry* **34**(7): 2076-2080.

Sturge, John M., ed. 1977. *Neblette's Handbook of Photography and Reprography Materials, Processes and Systems. Seventh Edition.* New York: Van Nostrand Reinhold, 42-69, 178-185.

Torigoe, M., et al. 1984. Kuroshiro shashin no choki hozonho [A Challenge in Preservation of Black-and-White Photographic Images]. *Scientific Publication of the Fuji Photo Film Co., Ltd.* **39**(29): 31-36.

Tuite, R.J. 1979. Image Stability in Color Photography. *Journal of Applied Photographic Engineering* **5**(4): 200-207.

Vittum, R.W., and A. Weissberger. 1954. The Chemistry of Dye-Forming Development. *Journal of Photographic Science* **2**: 81-96.

3.5 Supplemental Readings

Jacobson, Ralph C. 1978. *The Manual of Photography.* London: Focal Press Ltd., 222-225, 260-266, 443-445.

James, T. H., ed. 1977. *The Theory of the Photographic Process. 4th ed.* New York: Macmillan, 105-132, 390-393.

James, T.H., and G.C. Higgins. 1968. *The Fundamentals of Photographic Theory. Second Edition.* Dobbs Ferry, N.Y.: Morgan & Morgan, 95-96, 188-207.

Jenkins, Reese V. 1975. *Images and Enterprise: Technology and the American Photographic Industry.* Baltimore: The Johns Hopkins University Press.

Sturge, John M., et al., eds. 1989. *Imaging Processes and Materials: Neblette's Eighth Edition*. New York: Van Nostrand Reinhold.

Todd, H.N., and R.D. Zakia. 1974. *Practical Sensitometry: The Study of Tone Reproduction. Second Edition*. Dobbs Ferry, N.Y.: Morgan & Morgan, 192-207.

Weyde, E. 1962. Grösse und Form des entwickelten Silberkornes und seine Beziehungen zu bildwichtigen Eigenschaften [Size and Shape of the Developed Silver Grain and its Relationship to Image Properties]. *Photographische Korrespondenz* **98**(1): 7-12.

Sugar shanty. Abbotsford (?), Quebec. 1876. Alexander Henderson.
Contemporary print from copy negative of original print. National Archives of Canada/PA-149799.

4 Black-and-White Processing

4.1 Introduction

Photograph conservators are often called upon to make copies or duplicates of original photographs to act as surrogates for study purposes or for publication. Conservators may also need to document their work using photographs or may need to produce photographs for other reasons. This chapter is an introduction to photographic technology in that it covers the areas of basic sensitometry (the study of the response of photographic materials to light), basic processing control and techniques, and the techniques required to produce well-processed and highly stable black-and-white photographs.

The material covered here is a necessary precursor to the chapters on duplication and copying and on chemical treatments. It is also important for parts of Chapters 5, 8, and 10 where it may be necessary to prepare sample photographs.

4.2 The Characteristic Curve and Experiments — Introduction

Over many years, standard techniques have been developed to measure the response of black-and-white photographic materials to light. These techniques involve quantifying both the light that strikes a given material and the effect the finished photograph has on light after it has been exposed and processed.

Light incident on an object, such as when a film is exposed in a camera, is measured in either footcandles or metercandles. A footcandle is the amount of light incident on a surface which is a foot away from a light source with an intensity of one candela. Similarly, a metercandle is the light incident on a surface from a one-candela source one meter away. Both these definitions assume the surface is perpendicular to the light source and the candela is related to the earlier standard of candle power. Light incident on a surface when measured this way is referred to as illuminance. Photoelectric meters are available to measure illuminance in either metercandles or footcandles.

Measuring the illuminance on a photographic material is not the same as measuring exposure. To measure exposure, the amount of time the light was illuminating the photographic sample must also be known. Exposure is therefore defined as:

$$H = I * T$$

where H is exposure, I is illuminance and T is time. The most often used units for exposure are meter-candle-seconds (MCS). Exposure, however, is an inconvenient measure as it does not relate well to the subjective impression of brightness of the human visual system. Since visual response is approximately logarithmic the log to the base 10 is taken of exposure and this is referred to as the log exposure (log H).

Now that we can define the quantity of light exposing the photograph, a method is required to measure the ability of parts of a photographic image to affect light. In the case of photographs viewed or printed by transmitted light such as films and plates, it is necessary to expose the image to a known illuminance and to measure the light transmitted by the film. The opacity, or light-stopping ability, of a material may then be defined as:

$$\text{Opacity} = \frac{\text{Incident Light}}{\text{Transmitted Light}}$$

For several reasons, opacity has also not proved to be a convenient measure. Instead, the log to the base 10 of opacity has become the standard means of expressing the blackening of photographic materials. This measure is referred to as density or transmission density:

$$\text{Density} = \text{Log}_{10}\ (\text{Opacity})$$

If the material being measured is meant to be viewed by reflected rather than transmitted light, the density is the log of the ratio of light reflected from an unimaged portion of the photographic base material to the light reflected from the part of the image being measured. This is also referred to as reflection density:

$$\text{Density} = \text{Log}_{10} \left[\frac{\text{Light reflected from the base}}{\text{Light reflected from image}}\right]$$

Density has some basic advantages for describing the light-stopping power of a photographic material. As already mentioned, the response of the human visual system is approximately logarithmic and secondly, density may be used to estimate the amount of light-absorbing material in a photographic image.

Densities are typically read from a photographic sample using either a reflection or transmission photoelectric densitometer that has been designed to comply with standards for correct illumination of and collection of light from a sample.

The photographic image consists of areas with varying degrees of density. These different degrees of density correspond well with the actual amounts of light-absorbing material present in a photographic material and our visual perception of them. Therefore, the measurement of density is invaluable in determining the effect of such things as the aging of photographs or the effect of a particular restoration technique.

Now that the input and output of a photograph can be measured (i.e., quantified), a technique is required to relate the two quantities of log exposure and density. The standard way to do this is to plot a series of log exposures received by different portions of the photograph against the densities of the corresponding parts of the photograph on a chart. The resulting curve is referred to as the characteristic curve for that material and processing condition. The characteristic curve was first defined in the late 19th century by Ferdinand Hurter and Vero C. Driffield, and for this reason, characteristic curves are also often referred to as "H & D curves." The curve for any particular material shows the effect of a wide range of degrees of exposure, from underexposure to overexposure, and the effect of development for a set length of time in a particular developer.

To produce a characteristic curve such as the one pictured in Figure 4.2, it is necessary to expose a film to a number of different and controlled exposures on different parts of the film sample. This could be done by making many different exposures, one at a time, on different areas of the film. A more practical and simpler method, however, is to use an optical wedge to modulate the light from a single light source. The wedge or step tablet illustrated in Figure 4.1 provides varying degrees of exposure to a photographic sample by reducing the amount of light that passes through each step. The step tablet used most often in the following experiments is composed of 21 different degrees of density starting from very little density and increasing by nearly equal increments averaging 0.15. Once a sample has been exposed in contact with the step tablet and processed, density readings of all 21 steps are taken and each of these readings is plotted against the log exposure received by each step on a graph. The horizontal axis represents the various log exposures, and the vertical axis represents the corresponding densities. The result of plotting the density values against the corresponding exposure values is a series of points which, when joined using a French curve, or spline fitting technique, form a characteristic curve.

For the purposes of the experiments in this guide, the actual size of the units on the density axis must equal the size of the units on the log exposure axis, so that a direct one-to-one correlation between density and log exposure can be made. This will facilitate work in Chapter 6. This section contains five experiments that present the components of the characteristic curve and demonstrate the significance of each. Students will draw curves, determine log exposure values, and manipulate the curve through development time and exposure time.

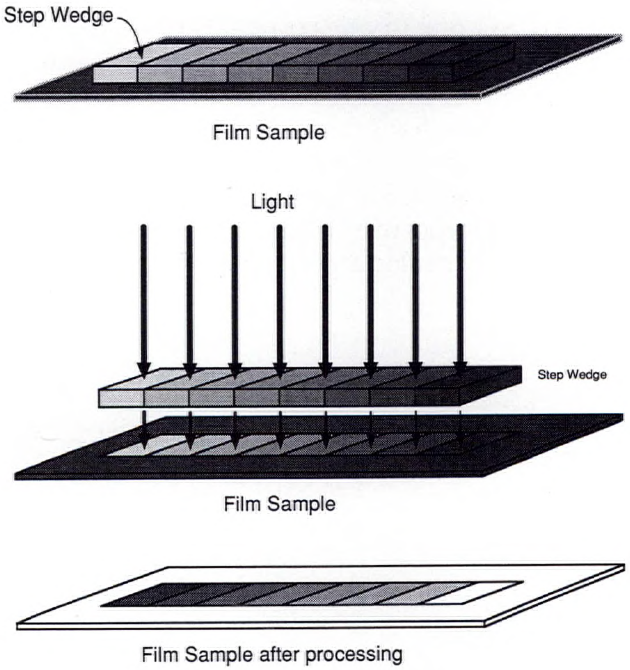


Fig. 4.1: The use of a step tablet to modulate the light received by a test sample.

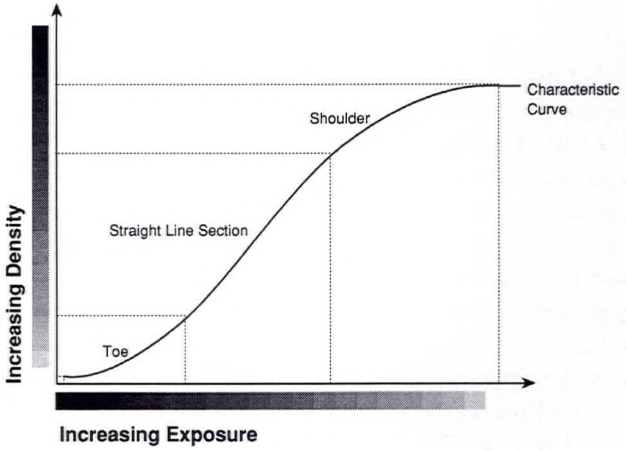


Fig. 4.2: Sample characteristic curve.

Figure 4.2 shows a simplified characteristic curve for an imaginary photographic film. Some photographic materials may produce significantly different shaped curves. In general, however, there are four significant parts to most characteristic curves. These are:

1. *Base Density plus Fog*: This is the extreme left region of the curve where the film gives no response to the varying degrees of exposure it receives. The small density evident here is a result of two factors. First, there are always a small number of silver halide grains that, despite not being exposed to light, will develop into metallic silver grains during the

process of development. Second, the base or support material contributes some density. These two densities add together to produce "base plus fog."

2. *The Toe*: This region follows the "base plus fog" region on the curve and indicates an initial response from the film to increasing exposure. Densities in this region increase very slowly at first with increasing exposure and then more rapidly as the straight-line portion of the curve is approached. In the case of a pictorial negative film, this portion of the curve would contain information from the darker or "shadow" areas of the initial scene. When printed, these shadow details would become better separated and more recognizable as the toe approaches the straight-line portion. The toe region varies in length and shape according to the type of film (see Section 4.4.2).

3. *The Straight Line*: This is the mid-section of the curve immediately following the toe. In the straight-line portion, the increase in density or tone from one step to the next is even and constant. In other words, the slope of the curve is constant. This region of the curve produces the greatest degree of tonal separation. Some films have no straight-line section.

4. *The Shoulder*: This is the right section of the curve immediately following the straight-line portion, where the slope of the curve decreases. Thus as log exposure increases, the resulting increase in density becomes less and less. If the curve is carried far enough to the right, the slope of the characteristic curve will be 0, indicating no further useful response to subject contrasts in that region of the curve.

Normally, when a film is exposed to a scene in a camera, or to another film in a contact frame, a wide variety of log exposures will occur in different places on the film. Not all scenes, or originals, will produce as long a range of log exposures as that produced with the step tablet used to make the curve illustrated in Figure 4.2. Depending on the time of the exposure and illuminances on the film, all the log exposures may fall on the straight-line portion of the characteristic curve. If a scene produces a wide range of illuminances on the film, the scene may be reproduced using the toe, the straight-line section, and the shoulder. The difference between the highest log exposure and the lowest is referred to as the log exposure range. The total contrast of the original scene is closely related to the log exposure range produced on the film but may be much greater due to flare. The difference between the highest and lowest density of the exposed and processed film can be thought of as a measure of the film's final total contrast.

The maximum useful log exposure range of a film is the log exposure range over which the film responds to changes in log exposure by producing discernible changes in density. For pictorial films the minimum useful log exposure is most often determined as being the log exposure that produces a density of 0.10 above the "base plus fog" density of the material. The maximum useful log exposure is less easily determined. It is most often approximated by finding the point on the shoulder portion of the curve where the slope is equal to 0.20. The difference between the minimum and maximum useful log exposures is the maximum useful log exposure range.

If the slope of the straight-line section of the curve was equal to one, and the log exposures resulting from the scene being photographed could all be placed on the straight-line section of the curve, then for every change in log exposure there would be an equal change in density. This one-to-one relationship between changes in log exposure and changes in density would result in accurate large area tonal reproduction of the original scene. Not only would the overall contrast of the scene and film match but all the changes in all the intermediate tones would be equal. While this says nothing about the sharpness of the resulting image, accurate tonal reproduction is extremely desirable when duplicating original photographs.

If the slope of the curve were greater than one, then the resulting densities will be expanded and this can be used, within limits, to compensate for very low contrast originals. If the slope is less than one, then the tones of the original scene will appear to be compressed. This can be used to compensate for an extremely high-contrast scene or original.

The ability of a photographic material and a particular set of processing conditions to alter the contrast of the original scene may be determined using the characteristic curve in a number of different ways. If the log exposure range falls entirely on the straight-line section of the curve, then only the slope of the straight-line section needs to be determined. The slope of the straight-line section is called the gamma of the material. In many cases the film material will not even have a straight-line section or the best scene reproduction will be judged to occur when the toe and the straight-line section are used. In these cases, the average slope of the part of the curve being used is taken and this is referred to as the average gradient. Most often in pictorial photography a special version of the average gradient is used, known as the contrast index. The contrast index (CI) is the slope of a straight-line that joins specific minimum and maximum densities on the D-log H curve of a particular photographic material under particular development conditions. These techniques are discussed below.

Gamma: Since gamma is the slope of the straight-line portion of the curve, it is the simplest to calculate. Two conveniently separate points on the straight-line section of the curve are selected. The ratio of the difference between the density values for the two points and the difference between the log exposure values is the gamma. So for two points, a and b, on the straight-line section of the characteristic curve where b has the greater log H:

$$\text{Gamma} = \frac{\text{Density}_b - \text{Density}_a}{\text{Log H}_b - \text{Log H}_a}$$

Fig. 4.3: Calculation of gamma.

Average Gradient: The average gradient is the slope of a line connecting two points on the characteristic curve. Average gradient is therefore a measure of the average slope over any specified range of the characteristic curve. Thus, while a characteristic curve may have only one gamma, it may have many different average gradients, depending on the section of the curve being measured. When discussing the average gradient, it is essential that the end points of the section of the curve and how they were chosen be described.

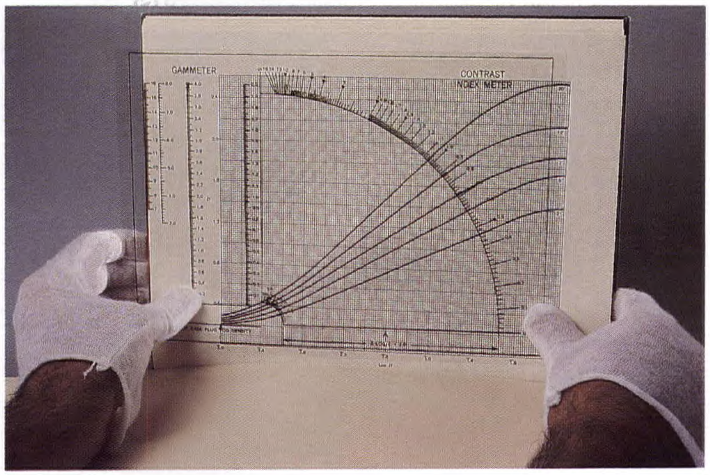


Fig. 4.4: Determining the contrast index.

Contrast index is determined using a special transparent meter placed on a characteristic curve as illustrated in Figure 4.4. The bottom or zero line of the meter is aligned with the "base plus fog" line of the curve. The meter is then moved back and forth until the number intersecting the inner curve and outer curve of the meter are the same. This number is the contrast index.

The characteristic curve of photographic papers can be treated very similarly to the curves produced by films with some exceptions. With photographic papers, the useful log exposure range is constrained by the fact that reflection densities by their nature rarely go higher than a density of 2.00 or 2.20. Thus increasing exposure above the point that produces a density of 2.00 is of little value. The standard method by which the useful log exposure range of a paper material is computed is different than the methods used to determine it for films. For papers, the minimum useful log exposure is that which produces a density of 0.04 above "base plus fog". The maximum useful point is the log exposure required to produce a density of 0.90 of the density at which the slope of the curve is 0.005. This is well approximated by calculating the log H required to produce a density of 0.90 times the maximum density of the paper. The difference in log exposure between these two points is the useful log H range of photographic papers.

4.2.1 Experiment 1: Exposure Template

Purpose

To assemble an exposure template to be used in the experiments in this chapter and throughout the training program. The template will include a step tablet and resolution targets stripped into a larger piece of film leader.

Introduction

As outlined in the introduction to this section, a step tablet of 21 steps is a valuable tool in determining the effect of light and processing on photographic materials. The characteristic curve gives a great deal of information about the large area contrasts of the material being tested but says little about the sharpness of the photograph. For this reason, the exposure template also incorporates a means of comparing the resolution of photographic materials, i.e., its ability to reproduce fine detail. The resolving power of a photographic material is dependent on many factors: the type of light used for the exposure, the diffuseness of the light and its intensity; the nature of the photographic material itself (such as a film's spectral sensitivity and the structure of the image silver in that particular emulsion); the manner of development; and any after-treatments. Because of the many variables involved, including limitations in the resolution target being used, the resolution target used in this and subsequent chapters is used only for purposes of comparing film and paper resolutions before and after various treatments. It will not be used to determine the actual resolving power of a test sample. Instead, it will be used to observe changes produced in a developed sample by a range of variables, sometimes in comparison to a sample processed under optimum conditions.

In this and the other experiments, the imaged resolution targets will be read by determining the smallest lines that can be discerned in the sample when viewed under bright field illumination and a magnification of 40 times in a microscope.

The resolution target to be used is a reduced copy of a target that was developed by the Rochester Institute of Technology. This target contains alphanumeric characters which must be correctly identified under the microscope to read the resolution of the target image. The modified target used in the exposure template should have a minimum resolution of 160 lines per millimeter. Other targets of similar or better resolution, such as the U.S. Air Force targets, may be substituted for the supplied copy of the RIT target. The exposure template constructed in this chapter will be used frequently in subsequent experiments. It is important to keep the piece of film free of fingerprints, dust, and scratches, to ensure consistent results.

Materials and Apparatus

- Kodak Black Aero Leader # 5986, 4" × 5" piece
- Kodak photographic step tablet no. 2 (21 steps)
- reduced RIT Alphanumeric Resolution Target
- sharp X-acto knife
- Scotch ® 3M Polyester Film Tape no. 850 (silver)
- transmission densitometer

Procedure

1. Measure and record all densities from the Kodak photographic step tablet no. 2 using the neutral filter on the densitometer.
2. Obtain two resolution targets, with negative and positive images on each, measuring approximately 0.5 mm × 1.5 mm. Using the microscope and tables from the RIT test object booklet, determine the resolution of the targets and record them.
3. Take a 4" × 5" piece of Kodak Black Aero Leader # 5986. Use the X-acto knife to cut out a piece in the center just larger than the no. 2 step tablet.
4. Cut out two sections of the leader near either end of the step tablet just smaller than the resolution targets.
5. Tape the step tablet in place with the emulsion side facing away from the leader, using thin strips of tape on the non-emulsion side. Tape the resolution targets into the aero leader, emulsion side facing away from the leader. This will cause the resolution targets to be lower than the leader (see Figure 4.5) and assure good contact of the targets to test samples.
6. Keep the exposure template in a Mylar sleeve at all times when not in use.

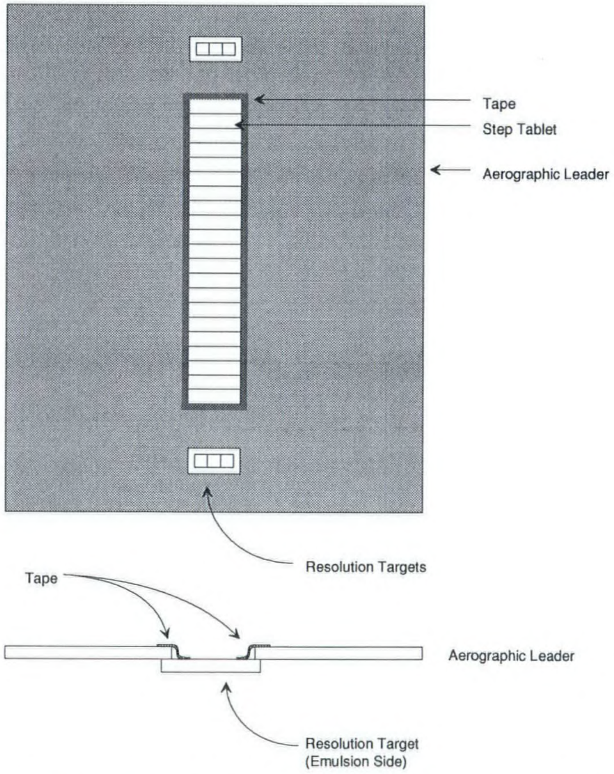


Fig. 4.5: Design of the exposure template.

4.2.2 Experiment 2: Preparing the Graph Paper — Log H Co-ordinates

Purpose

To prepare Kodak Curve Plotting Graph Paper by setting up the log H co-ordinates.

Introduction

Kodak Curve Plotting Graph Paper contains 21 vertical lines, one line per step of the step tablet. Each step of a Kodak step tablet is approximately 0.15 density units different than the one adjacent to it. When plotting the characteristic curve of a negative on this paper, step 21 of the step tablet (the high-density area) sits on the far left vertical line. Step 1 (low-density area) lies on the line furthest to the right. All other points fall in between.

The exposure template from Experiment 1 is used to produce images of the step tablet on negative materials. The density differences between the steps in this template are used as the vertical co-ordinates. The Kodak Curve Plotting Graph Paper is set up with 0.15 density units between each vertical line; however, this is only an approximation. For a more accurate curve, it is necessary to subtract the density values of each step of the exposure modulator from the one above it. These values will be used as the new, more accurate vertical co-ordinates.

Materials and Apparatus

- transmission densitometer
- exposure modulator from Experiment 1
- Kodak Curve Plotting Graph Paper
- pencil
- straightedge

Procedure

1. Using the transmission densitometer, measure and record the neutral density values of every step of the Kodak photographic step tablet no. 2 , which was incorporated into the exposure template.

2. Subtract the density differences of each of the steps on the modulator from the one preceding it (see Table 4.1).

3. On the Kodak Curve Plotting Graph Paper, step 21 acts as the "0" point at the lower left axis of the graph. Mark off each step, the density difference, on the horizontal axis (log H) of the graph paper. Proceed from left to right, beginning with step 21. (Each of the smallest increments on the horizontal scale is equal to 0.02 density units.)

4. Draw vertical lines from the new co-ordinates on the log H axis to 3.0 density on the Kodak Curve Plotting Graph Paper, allowing enough space for a title block at the

top. (Most curves have a maximum density of less than 3.0, and thus will easily fit on the calibrated paper.)

5. The vertical axis is also marked off in increments of 0.02 density units.

6. Make photocopies as required of the prepared graph paper and use these for plotting curves throughout the training program. Save the original for making additional copies when necessary.

Table 4.1: Typical Modulator Density Values

Step #	Density Value	Density Difference Between Steps
21 (high density)	2.95	
20	2.80	0.15
19	2.67	0.13
18	2.52	0.15
17	2.37	0.15
16	2.23	0.14
15	2.09	0.14
14	1.95	0.14
13	1.80	0.15
12	1.64	0.16
11	1.50	0.14
10	1.36	0.14
9	1.21	0.15
8	1.06	0.15
7	0.92	0.14
6	0.77	0.15
5	0.63	0.14
4	0.48	0.15
3	0.34	0.14
2	0.19	0.15
1 (low density)	0.05 (shadows)	0.14

4.2.3 Experiment 3: Use of a Point Light Source and a Footcandle Meter, and the Calculation of Log Exposure

Purpose

To gain familiarity with using a point light source and contact printing frame. To demonstrate the inverse square law; to calculate the log exposure at the exposure plane; and to determine the actual log exposure values for the D-log H graph.

Introduction

The point light source is used to provide even illumination at the exposure plane. The evenness of illumination is controlled by the shape of the lamp housing and the distance of the light source from the exposure plane. The illuminance on the exposure plane is governed by the distance and intensity of the source of light from the exposure plane. The change in illuminance when either the distance or intensity is changed is governed by the inverse square law. Thus:

$$\text{Illuminance} = \frac{\text{Intensity}}{\text{Distance}^2}$$

This relationship is useful for adjusting the illuminance on the film plane of a contact printing frame. It does not work for enlargers. For example, if the initial illumination is 100 footcandles, the desired illumination is 50 footcandles, and the distance between the light source and subject is 10 feet, one can calculate the necessary change in the distance between light source and subject:

I_1 = 100 footcandles
I_2 = 50 footcandles
S_1 = 10 feet
S_2 = ?

and since,

$$I_1 = \frac{\text{Intensity}}{S_1^2}$$

and,

$$I_2 = \frac{\text{Intensity}}{S_2^2}$$

then for equivalent intensity,

$$\frac{I_1}{I_2} = \frac{S_2^2}{S_1^2}$$

$$S_2^2 = \frac{S_1^2 \times I_1}{I_2}$$

Substitution gives

$$S_2^2 = \frac{(10)^2 \times 100}{50} = \frac{10{,}000}{50} = 200$$

Therefore, $S_2^2 = 200$; $S_2 = 14.14$ ft.

In other words, halving the distance is equivalent to increasing the intensity of the source by a factor of four and doubling the distance is equivalent to decreasing the intensity of the light source to one-quarter of its previous output. The point light source used in the Photograph Conservation Laboratory is a NuArc system with a lamp housing, lamp, and a voltage control unit. The control unit alters the intensity of the lamp (from a setting of 1 to 6). In this case, the illuminance that results at the film plane is measured using a footcandle meter.

The illuminance value obtained through the use of a footcandle meter must be converted to its equivalent value in metercandles before log H values may be determined. The footcandle reading is multiplied by 10.76391 to give metercandles. Metercandles multiplied by the length of exposure time gives meter-candle-seconds.

The log to the base 10 of the meter-candle-seconds for a particular exposure is the log exposure at the film plane. By subtracting the individual densities of the step tablet from the log H at the film plane, the actual log exposures for each step on the horizontal axis of the characteristic curve are determined (see Figure 4.6). If the log exposure at the film plane is a small figure, negative logarithms will result. Of the many notations possible for negative logarithms, bar notation will be used as it is the traditional notation used in photographic science. Bar notation and negative logarithms are discussed in Section 4.2.3.1.

Materials and Apparatus

- exposure template from Experiment 1
- prepared (calibrated) Kodak Curve Plotting Graph Paper
- Kodak Plus-X Pan 35-mm Film, 8" in length
- NuArc point light source
- footcandle meter
- Hope 152 Black-and-White Film Processor

Procedure — Part I

1. Connect the point light source to the control unit and set at intensity 6, the most intense light.
2. Raise the lamp and lamp housing to a height that covers an area approximately 10 inches in diameter.
3. Measure and record the illuminance level at the exposure plane with the footcandle meter.
4. Move the probe of the meter over the illuminated area and determine, by fluctuations of the meter, where the illumination becomes uneven.
5. Raise the point light to twice the height and repeat steps 3 and 4.
6. Lower the light source to one-half the initial height. Repeat steps 3 and 4.

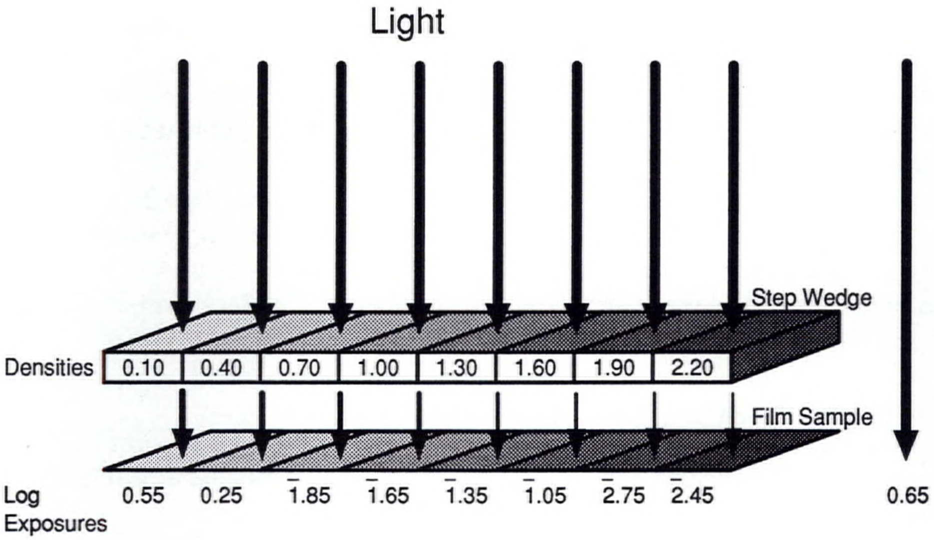


Fig. 4.6: Determining the log exposure values received by a sample exposed using a step tablet.

7. Reposition the light source so that the exposure plane is evenly illuminated in a 20-inch diameter area and record the illuminance value.
8. Measure and record the illuminance value which results for each of the intensity settings (1 through 6) for the 20-inch diameter area.
9. Using the inverse square law, calculate the predicted illuminances for steps 1 through 6, using the formula provided earlier. Compare the results to the results actually obtained.

Procedure — Part II

1. Convert the footcandle measurements from Part I to metercandles by multiplying the footcandle values by a factor of 10.76391.
2. The exposure at the film plane is equal to illuminance × the length of exposure. Adjust the intensity of the source and/or the time of exposure to produce an exposure of 4.50 meter-candle-seconds.
3. To obtain the log exposure at the film plane, find the logarithm of the meter-candle-seconds.

Procedure — Part III

1. Expose a film sample under the point light source, using the exposure template from Experiment 1 and the exposure from Part II.
2. Process the film in the Hope 152 Black-and-White Film Processor or use an equivalent processing method, according to the instructions given in Chapter 2.
3. Repeat steps 1 and 2, varying the exposure until only one or two steps of the imaged step tablet are equal to the "base plus fog" of an unexposed area of the sample.
4. Take the log exposure at the film plane as determined in Part II. Subtract from it all the density values from each step of the step tablet. These figures are the actual log exposure values received by the film sample under each step in the step tablet (see Table 4.1).

Example:

Film plane log exposure: 0.65
minus
density value from step 1: $\underline{2.25}$
actual log exposure value: $\bar{2}.40$

(bar notation when relative log H < density value)

5. These log exposure values correspond to the steps on the horizontal axis of the graph. Place these values on the graph. Examples of typical log exposure calculations are given below.
6. Read the neutral filter density for each step of the step tablet image on the processed film sample. Plot the characteristic curve on a piece of prepared Kodak Curve Plotting Graph Paper, from Experiment 2. Join the points into a smooth curve using either a French curve or a spline.

Following are examples of typical log exposure calculations.

1. $\begin{array}{r} 0.65 \\ \underline{2.25} \\ \bar{2}.40 \end{array}$	2. $\begin{array}{r} 0.65 \\ \underline{2.15} \\ \bar{2}.50 \end{array}$	3. $\begin{array}{r} 0.65 \\ \underline{2.06} \\ \bar{2}.59 \end{array}$
4. $\begin{array}{r} 0.65 \\ \underline{1.98} \\ \bar{2}.67 \end{array}$	5. $\begin{array}{r} 0.65 \\ \underline{1.87} \\ \bar{2}.78 \end{array}$	6. $\begin{array}{r} 0.65 \\ \underline{1.76} \\ \bar{2}.89 \end{array}$
7. $\begin{array}{r} 0.65 \\ \underline{1.64} \\ \bar{1}.01 \end{array}$	8. $\begin{array}{r} 0.65 \\ \underline{1.52} \\ \bar{1}.13 \end{array}$	9. $\begin{array}{r} 0.65 \\ \underline{1.41} \\ \bar{1}.24 \end{array}$
10. $\begin{array}{r} 0.65 \\ \underline{1.26} \\ \bar{1}.39 \end{array}$	11. $\begin{array}{r} 0.65 \\ \underline{1.11} \\ \bar{1}.54 \end{array}$	12. $\begin{array}{r} 0.65 \\ \underline{0.97} \\ \bar{1}.68 \end{array}$

13. $\begin{array}{r} 0.65 \\ \underline{0.81} \\ \bar{1}.84 \end{array}$ 14. $\begin{array}{r} 0.65 \\ \underline{0.87} \\ \bar{1}.78 \end{array}$ 15. $\begin{array}{r} 0.65 \\ \underline{0.56} \\ 0.09 \end{array}$

16. $\begin{array}{r} 0.65 \\ \underline{0.48} \\ 0.17 \end{array}$ 17. $\begin{array}{r} 0.65 \\ \underline{0.42} \\ 0.23 \end{array}$ 18. $\begin{array}{r} 0.65 \\ \underline{0.39} \\ 0.24 \end{array}$

19. $\begin{array}{r} 0.65 \\ \underline{0.37} \\ 0.28 \end{array}$ 20. $\begin{array}{r} 0.65 \\ \underline{0.36} \\ 0.29 \end{array}$ 21. $\begin{array}{r} 0.65 \\ \underline{0.35} \\ 0.30 \end{array}$

Analysis

Prepare a report in which you discuss the results of this three-part exercise.

Questions

1. The log of 2 is 0.30. The light source was moved from the original height setting to twice and one-half of this original distance. What was the log illuminance range between the maximum and minimum lamp heights?
2. What is the log illuminance range that can be produced with the point light source?
3. How does the characteristic curve differ from the illustration of a typical characteristic curve in Figure 4.2?

4.2.3.1 Appendix: Bar Notation and Negative Logarithms

The exponential function with base 10, $y = 10^x$, has the inverse function $x = \log_{10} y$. When a logarithm is taken of a value y, it is as though the equation $y = 10^x$ is being solved for x. For example, if $y = 1$ then $1 = 10^x$ and so x must equal 0. Similarly, if $y = 10$ and $10 = 10^x$ then x must equal 1. If y is 100 then x is 2 and so forth. Usually, the x and y are switched around as the custom is for y to be the dependent variable. So

$$y = \log_{10} x$$

is the logarithmic function and is read "y equals the logarithm of the number x to the base 10."

The log to the base 10 is taken of a photographic materials opacity to produce a density value and of the exposure it has received to produce a log exposure. It is these values that are used to generate characteristic curves.

Taking the Logarithm

Traditionally, logs to the base 10 have been computed using tables. The number the logarithm is to be taken of (x) is first written in scientific notation. For example, if the number 4500 is written in scientific notation, it becomes 4.5×10^3. This number has two parts of interest. The factor 4.5 and the power 10 is raised to, in this case, the exponent 3, which is called the characteristic. To find the log of 4500, we determine what the characteristic is and then look up 4.5 in a table of logarithms. The table gives a decimal number, which is called the mantissa. When these numbers (the characteristic and mantissa) are found, they are added together. In this case, a logarithm table would give the value 0.6532 for 4.5. Adding 3 and 0.6532 together gives 3.6532, which is the $\log_{10}$ of 4500.

With the low cost of calculators, the necessity for using tables of logarithms has mostly disappeared. Unfortunately, there is a complication in that when the log of a number less than 1 is taken, it produces a negative logarithm on a calculator. For example, if a calculator is used to determine the log of 0.63095, then the calculator will return the negative number -0.20. This value is a negative log and is a pure number. The traditional notation in the photographic sciences has been to write the logarithm of a number less than 1 as a number that has two parts. This notation is referred to as bar notation. Following the table look-up method, the number 0.63095 would be converted to 6.3095 × 10^{-1}. The 6.3095 would be looked up in a table of logs to give the value 0.80. Instead of adding the characteristic of –1 to this value to get the pure negative number the calculator gave of –0.20, the bar log is written $\bar{1}.80$. Thus the bar log is really a mixed number: the minus one is a negative

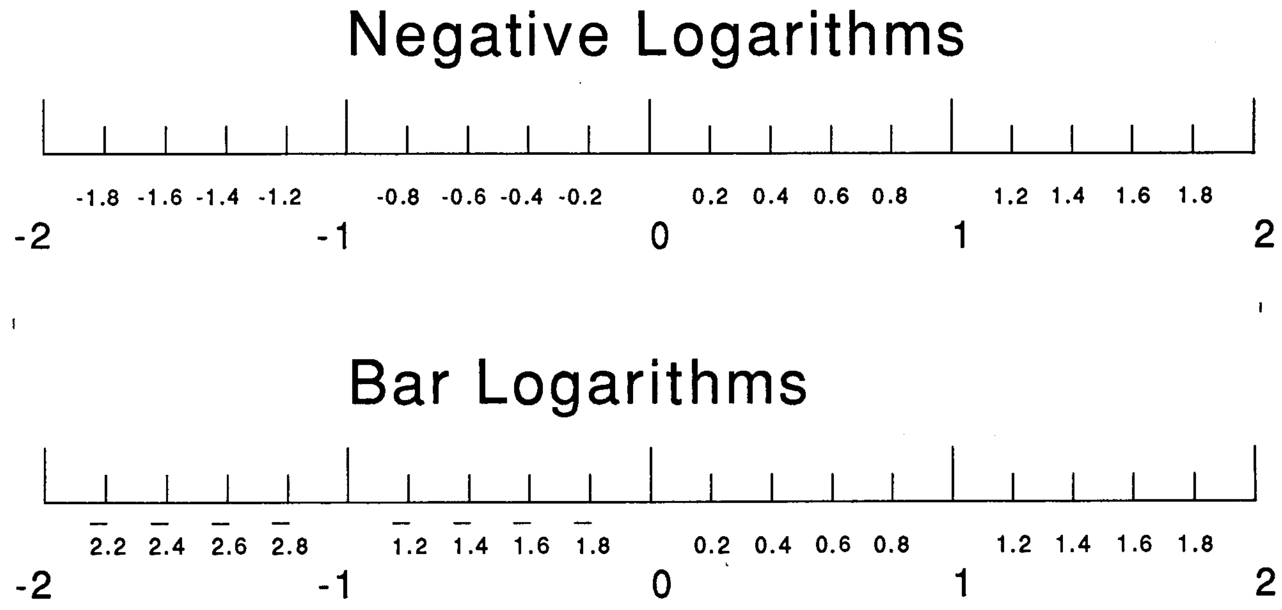


Fig. 4.7: Bar logs and negative log notations on the same scale.

number, and this is indicated by the bar over it whereas the 0.80 is a positive number.

This notation leads to what may first appear to be an unusual labelling of the log exposure scale in graphs. Figure 4.7 shows two scales between the values –2 and 2. The top scale is labelled with pure numbers including the value –0.20. The second scale is labelled using bar notation including the value $\bar{1}.80$. While the notations are different, the numbers represent the same value.

Often it is desirable to produce a bar log using a calculator. There are two methods for doing this. The first method is to substitute the calculator for a table of logarithms. In this case, the number is written in scientific notation, the characteristic is found, and the log of only the first factor is taken using the calculator. The second method is to take the log of the number and produce a negative log. If the mantissa is 0, the number may be written as a bar log, substituting a bar for the minus sign. If the mantissa is not 0, then 1 is subtracted from the integer portion of the number and the decimal portion of the number is subtracted from one. Using the value -0.20 as an example:

$$0 - 1 = -1$$

$$1 - 0.20 = 0.80$$

combining into a bar log gives,

$$\bar{1}.80.$$

Finding the Anti-Log

Often it is necessary not only to take the log of a number but to convert a log exposure back to exposure or in other words to take the anti-log of a number. To do this, the mantissa is looked up in a table of logarithms and the original factor found. The anti-log is then written in scientific notation with the characteristic becoming the power 10 is raised to. If a scientific calculator is used instead of a table, then 10 to the power of the mantissa is taken to find the factor.

When calculating log exposures, it is necessary to subtract the density of each individual step in the optical wedge and any other filtration from the initial log H measured at the film plane. The process for subtracting logarithms when a negative number is the result is somewhat different than for subtracting pure numbers. If a negative number is the result, the logs must be treated as mixed numbers, subtracting the mantissas separately and the characteristics separately and then combining the terms later. This must be done so that the mantissa always results in a positive number. Given

$$\begin{array}{r} 0.65 \\ \underline{-0.96} \end{array}$$

we borrow from the 6 to subtract 6 from 15

$$\begin{array}{r} 0.6\cancel{5} \\ \underline{-0.96} \\ 9. \end{array}$$

Now borrowing from the characteristic we take 9 from 15

$$\begin{array}{r} 0.\cancel{65} \\ \underline{-0.96} \\ .69 \end{array}$$

and adjusting the characteristic

$$\begin{array}{r} \bar{1}.\cancel{65} \\ \underline{-0.96} \\ .69. \end{array}$$

Now subtracting the characteristic we get -1 - 0 = -1 and combining terms gives

$$\begin{array}{r} \bar{1}.\cancel{65} \\ \underline{-0.96} \\ \bar{1}.69. \end{array}$$

Another example starting with a bar log is

$$\begin{array}{r} \bar{2}.25 \\ \underline{-1.27} \\ \bar{4}.98. \end{array}$$

4.2.4 Experiment 4: Response of a Photographic Material over a Wide Range of Exposures

Purpose

To demonstrate controlling the part of the D-log H curve that is used by changing the level of illuminance at the film plane.

Introduction

Exposure refers to total amount of light that the sensitive silver halide salts are exposed to. For example, the number of halide crystals that develop latent image specks and therefore become developable increases with greater exposure.

As the exposure increases so does the degree of density in the processed film or paper until well into the shoulder of the characteristic curve. Thus the shape of the characteristic curve does not change but the part of it being used, the location on the x-axis of the actual log exposure, changes. By increasing or decreasing the illuminance on the step tablet or by changing the exposure time, the log exposures occurring on the film are shifted to the right or left along the x-axis. Thus, when illuminance is reduced, the curve produced by using the step tablet will include more of the toe and straight-line portion. Well-exposed pictorial negatives should incorporate the toe and straight-line portion of the curve and may include the shoulder as well, depending on the luminance range of the scene. Over-exposed negatives would be exposed using only the straight-line portion and the shoulder region. Therefore, different portions of the characteristic curve may be used but the actual shape and gamma of the curve remain the same.

Materials and Apparatus

- Kodak Plus-X Pan Film (35-mm bulk roll) (5 ft. approx.)
- exposure template from Experiment 1
- prepared Kodak Curve Plotting Graph Paper
- scissors
- NuArc point light source
- Hope 152 Black-and-White Film Processor
- transmission densitometer
- contact printing frame

Procedure

1. *In absolute darkness*: using the point light source at its normal height setting (approx. 188 cm from film exposure plane) and the exposure template, expose an 8" strip of Plus-X Film. Hold the film and template together, emulsion side to emulsion side, in the contact printing frame. The exposure should be five seconds at intensity 3. Neutral density filters (for a total density of 1.3) should be in place in the light source. Label the sample "3."
2. Process the film sample in the Hope 152 processor at 50% base speed, take visual density readings, and plot the characteristic curve.
3. Repeat steps 1 and 2, changing the exposure by adjusting the exposure time, until only one or two steps of the imaged step tablet are equal to the "base plus fog" density of an unexposed portion of the image. Adjust the processing base speed (if necessary) until the gamma of the material is 1 ± 0.05.
4. Expose five more film samples at the same exposure time determined in step 3 but setting the lamp for intensities 1, 2, 4, 5, and 6, labelling each.
5. Process the exposed samples in the Hope 152 processor at the base speed that gave a gamma of approximately 1.
6. Plot the characteristic curve of each of the remaining five samples of exposed and processed film on a single sheet of prepared graph paper.

Analysis

Prepare a report on the results of the experiment.

Question

1. How does log H change with changes in illuminance?

4.2.5 Experiment 5: Effect of Development Time on Film Density

Purpose

To demonstrate the effect of varying development time on the gamma and resolution of film, given a constant exposure and developing temperature.

Introduction

Development time is the length of time that the developing agents in the developer solution have to act on the exposed silver halides, chemically reducing them to metallic silver. If development time is too long, not only are the exposed silver halides affected, the unexposed silver halides are also reduced to form an overall fog on the film. The apparent granularity of the image increases as development time increases. Gamma also increases with prolonged development. This is a particularly important consideration when accurate tone reproduction is required. Relatively short development times result in decreased gamma and additionally can cause uneven development of the film (at normal temperatures). Development time is the best way to control the gamma of any particular black-and-white photographic material.

Materials and Apparatus

- Kodak Plus-X Pan 35-mm Film, 5 ft.
- exposure template from Experiment 1
- prepared Kodak Curve Plotting Graph Paper
- neutral density filters
- NuArc point light source
- contact printing frame
- Hope 152 Black-and-White Film Processor
- transmission densitometer
- footcandle meter

Procedure

1. Set up the point light source so that the bottom of the lamp and filter housing are at normal height (118 cm from the film exposure plane). Using a footcandle meter, measure the light intensity of the light source at the film plane at intensity 3. It should read approximately 1.65 footcandles when the room is completely dark. To control more accurately the timer on the light source, the exposure time should be five seconds. This will require the use of neutral density filters (beginning with 1.30 density) when exposing the film samples.

2. Make a test exposure using the exposure template and a strip of Plus-X Film approximately 7" long. Process this test strip in the Hope 152 processor at 50% base speed. Read the visual densities of all steps of the wedge

and plot the characteristic curve on a piece of prepared Kodak Curve Plotting Graph Paper. The density range should be approximately 1.60 ± 0.15 and should extend from approximately 0.35 to 2.00 with a gamma of approximately 1. If the processed sample shows overexposure, increase the neutral density filtration and expose another test piece. To adjust the gamma upward, decrease the base speed of the processor and to adjust it downward, increase the speed.

3. When the ideal exposure and processor base speed are determined, expose five strips of film under the point light source and process them in the Hope 152 processor at 20%, 60%, 100%, 140%, and 180% of the base speed that produced a gamma of 1.0, respectively. For example, if 50% base speed gave a gamma of 1 process at 10%, 30%, 50%, 70%, and 90% base speed. If the calculated base speed exceeds 100%, use 100% base speed.

4. Measure and record the neutral density of all five processed film samples and plot their curves on a single piece of prepared Kodak Curve Plotting Graph Paper.

5. Measure and record the gamma of the straight-line portion of each of the film samples.

6. Using the RIT Alphanumeric Resolution Test Targets on the exposure template, measure and record the resolution of each film sample.

Analysis

Prepare a report on the results, discussing any variations noted.

Questions

1. How does development time affect density and gamma?

2. How does development time affect the film's resolution?

4.3 Processing Variables — Introduction

The experiments following demonstrate the effects of varying the developer type, developer temperature, developer pH, and agitation method on the characteristic curve of a particular film. These experiments also demonstrate the effect of fixing time and fixer pH on the overall density of film and paper. Further, the experiments show the relationship between inadequate fixing and the potential fading of silver gelatin emulsions. (The effects of inadequate fixing will be discussed again in Section 4.5.2.)

4.3.1 Experiment 6: Effect of Agitation on Development

Purpose

To demonstrate the effect of agitation on development.

Introduction

During development, only a small portion of the entire developer solution being used is in direct contact with the surface of the film. The developing agents contained in this area rapidly become depleted and require replenishment. Various agitation methods used while films and papers are in processing solutions puts the developing solution in motion, thus replacing the exhausted chemicals on the film's surface with a fresh, more active solution. Several methods are used to accomplish this task. Tray, rack-in-tank, and 35-mm small-tank rotation/inversion methods are all manual processing systems, while nitrogen burst and roller transport systems are used in semi-automated and automated processing systems. This experiment will examine the effect of the degree (rather than the type) of developer agitation on film density and resolution.

Tray processing is used to process sheet films in small quantities. The tray processing method requires little equipment and is relatively easy to set up and maintain. There are two basic techniques to hand processing in trays. One method, which will not be used here, is to place a stack of films or papers in a tray one at a time until several sheets are completely immersed. The bottom sheet is then placed on the top of the submerged stack. This process is repeated constantly during the development process and is referred to as tray shuffling. Perhaps better known is the technique of immersing a single sheet at a time and rocking the tray during development. Even development is somewhat difficult to obtain with tray processing as it strongly depends on the operator's technique. In particular with tray rocking, it is necessary to avoid directional patterns developing from a regular pattern of solution movement in the tray.

The *rack-in-tank* method of processing is used primarily for films in larger batches, although this method also can be used for processing single sheets. Film hangers designed to hold sheet films in 8" x 10", 5" x 7", or 4" x 5" formats are loaded with exposed film and placed in a film-hanger rack, which is immersed in the processing solution. The rack is then lifted out of the solution at regular intervals, tilted to the left and right, and re-immersed, as outlined in ANSI Standard PH4.29-1986. Replenishment of chemicals is almost always used in the rack-in-tank system, keeping chemical costs to a minimum.

Nitrogen-burst agitation uses the same setup as the rack-in-tank method, except that agitation results from nitrogen gas being released from the bottom of the tanks, at regular intervals and at a set pressure. As the gas is released from evenly spaced openings across the bottom, it bubbles quickly to the surface, agitating the solution as it rises. In this system, even distribution of the gas bubbles ensures even agitation when the system is set up correctly.

With the exception of the tray-shuffle technique, these three development systems move the solution around the film. *Roller-transport film processors* when well designed provide more effective and consistent results by moving the film through the solution and by the squeezing effect of the film rollers. The film is drawn through the solution by a series of rollers, the speed of which can be adjusted according to the type of film or desired results. Most experiments carried out in the Photograph Conservation Laboratory use the roller-transport method. However, because tray processing is the method most commonly available in photograph conservation darkrooms, it will be used in this experiment.

Materials and Apparatus

- Kodak Plus-X Pan 35-mm Film, 10 pieces, each 6"
- HC-110 film developer, Dilution B, 2 liters
- stop bath, 500 mL
- fixer, 2 baths, 500 mL each
- Kodak Hypo Clearing Agent, 500 mL
- Kodak Photo-Flo Solution
- 5 processing trays, 5" × 7"
- piece of glass, 4 1/2" × 6 1/2"
- masking tape
- contact printing frame
- exposure template from Experiment 1
- prepared Kodak Curve Plotting Graph Paper
- NuArc point light source
- neutral density filter(s), 1.30 total density
- transmission densitometer

Procedure

1. *In total darkness,* expose a test film sample using the exposure template in the contact frame. The initial light source intensity should be 3, with neutral density filters in place to provide a total neutral density of 1.30. An initial exposure time of five seconds should be used and an initial film sample should be tray processed with constant agitation. Exposure time and processing time should be adjusted to produce a sample with a gamma of 1.0 ± 0.05 and with at least one step and no more than two steps equal to the "base plus fog" of the film. When the correct

exposure and development have been determined, expose six more pieces of Plus-X Film in the contact printing frame under the point light source. The exposure for all six film samples must be identical. Label each film sample.

2. Using fresh developer solution for each film sample, process each of the samples, one at a time in the following manner:

   a. Tape the film sample to the glass, emulsion side up. Use a small strip of masking tape at either end of the sample. This is done to keep the sample from floating to the top of the developer solution during the no-agitation condition. All samples are taped this way for consistency.

   b. Using the manufacturer's recommended development time and temperature (five minutes at 20°C), develop each film sample. Slip the piece of glass (film emulsion side up) into the developer, using for each sample one of the following six methods of agitation:

Sample 1: No agitation.
Sample 2: Agitate 5 seconds every minute.
Sample 3: Agitate 5 seconds every 30 seconds.
Sample 4: Agitate 10 seconds every 30 seconds.
Sample 5: Agitate 20 seconds every 30 seconds.
Sample 6: Agitate continuously.

   Except for the variation in agitation times and intervals, follow the agitation method for tray processing outlined in ANSI Standard PH4.29-1986. This will involve ensuring that the trays are filled to a depth of 2 cm and alternately raising the left side and the lower near side of the tray and then the right side and lower near side of the tray 1 to 2 cm with a smooth motion.

   c. Immerse each film sample in the stop bath for 15 seconds with agitation, and then remove it from the glass support. Fix each sample using two baths, five minutes per bath, with agitation. Wash the film for five minutes in running water. Immerse the sample in Kodak Hypo Clearing Agent for two minutes with agitation. Continue washing for 20 minutes. Immerse in diluted Kodak Photo-Flo solution for 30 seconds and hang to dry.

3. Using the transmission densitometer neutral filter, read and record the densities of all steps of the step tablet for each of the six samples. Plot all of the characteristic curves for the samples on a single sheet of prepared Kodak Curve Plotting Graph Paper.

4. Determine the resolution of each of the samples by reading the RIT Alphanumeric Resolution Test Targets on each.

Analysis

Prepare a report that discusses the effects of each degree of agitation on the characteristic curve and resolution of Plus-X Film.

Questions

1. How does agitation affect the development of film samples?

2. Is there a point at which further agitation is of no benefit?

4.3.2 Experiment 7: Effect of Temperature on Development

Purpose

To demonstrate the effect of varying developer temperature on the characteristic curve and resolution of a film.

Introduction

The developing agent in photographic developers reduces exposed silver halide grains to metallic silver. As with any chemical reaction, the chemical reduction process is affected by temperature: in general, the greater the temperature, the greater the rate of reaction; the lower the temperature, the slower the reaction.

Materials and Apparatus

- Kodak Plus-X Pan 35-mm Film, 4 pieces, each 6" long
- HC-110 film developer, Dilution B, 1.5 liters
- stop bath, fixer, and Kodak Hypo Clearing Agent, 1.5 liters each
- exposure template from Experiment 1
- prepared Kodak Curve Plotting Graph Paper
- 4 small 35-mm tanks and reels
- thermometer
- NuArc point light source
- neutral density filter(s), 1.30 total density
- contact printing frame
- transmission densitometer

Procedure

1. *In total darkness,* using the exposure template and contact printing frame, expose four pieces of Plus-X 35-mm Film under the point light source. The exposure for all four film samples should be identical. The light source intensity should be 3, with 1.30 neutral density filters in place. As in Experiment 5, exposure time should be determined from an initial exposure of five seconds. Label each sample. Load each sample onto a reel, and place the reels into the tanks.

2. The processing of all four samples will be identical, except for the temperature of the developer. All other processing chemicals

will be at room temperature. Process each sample, using the following developer temperatures:

Sample 1:	15°C
Sample 2:	20°C
Sample 3:	25°C
Sample 4:	30°C

Develop each sample for the manufacturer's recommended time (five minutes). Use fresh solution for each sample. Agitate for five seconds every 30 seconds, as described in ANSI Standard PH4.29-1986.

3. The post-development treatment will be identical for all four samples:

stop bath:	15 seconds, with agitation
fixer:	two 5-minute baths, with agitation
water rinse:	1 minute, with agitation
Kodak Hypo Clearing Agent:	2 minutes with agitation

4. Remove samples from reels. Wash in running water for five minutes. Dry the samples.

5. Measure and record neutral density readings for all tones on the step tablet.

6. Plot all four characteristic curves on a single sheet of prepared Kodak Curve Plotting Graph Paper.

7. Measure the resolution of each film sample.

Analysis

Prepare a report that discusses the effects of increased temperature on the characteristic curve and resolution of Plus-X Film.

Questions

1. How does the developer temperature affect the density and apparent granularity of the image silver?

2. Consult the supplemental readings to determine what developer component is retarded in its action by low solution temperatures.

3. What steps can be taken to ensure consistent solution temperature during processing?

4.3.3 Experiment 8: Action of Developer Components during Processing

Purpose

To demonstrate the effect during processing of each component of a typical developer on an exposed silver halide emulsion.

Introduction

The developer is an alkaline solution that is designed to reduce the exposed silver halide grains in an emulsion to metallic silver without reducing the unexposed grains. The solution must also meet several other criteria to be practical:

1. It must resist aerial oxidation;
2. It should yield colorless (non-staining) and soluble oxidation products;
3. It should be innocuous and nontoxic; and
4. It should be ecologically acceptable in its reduced and oxidized forms (Lee, 1984).

The developer is composed of several chemicals that assist in maintaining the criteria mentioned above. These components, which appear in various combinations depending on the material to be developed and the degree of activity desired for the developer, include a *developing agent* or agents, an *accelerator*, a *preservative*, a *restrainer*, and *sequestering agents*. These components are dissolved in water to make a developing solution (developer) and may be replenished during processing as parts of the developer are used up. Some developers are not designed to be replenished. They are used to a certain point of depletion and then discarded. Often developers are used as "one-shot" developers where a single batch of materials is processed and then the developer is discarded.

The *developing agent* is a reducing agent. It reduces the exposed silver halides to black metallic silver at a greater rate than it reduces the unexposed grains. If left long enough, the developing agent will reduce a visually noticeable proportion of unexposed silver grains to metallic silver as well. The developer is a molecule that is capable of donating an electron to a silver ion in order to reduce it to a neutral silver atom. Fortunately, the unexposed silver grains in an emulsion are somewhat insulated by a charge barrier caused by adsorbed halide ions and do not readily accept electrons from the developing agent. Exposed silver halides, however, have a latent image surface speck on or beside which the developing agent can be adsorbed. Once the developing agent is adsorbed, it easily donates an electron to the silver halide crystal and becomes oxidized.

Many different organic developing agents have been used throughout the history of photography. Some of the more familiar agents include p-dihydroxybenzene (hydroquinone), p-methylaminophenol sulfate (Metol), 1,2,3-trihydroxybenzene (Pyrogallol, pyrogallic acid), 2,4-diaminophenol dihydrochloride (Amidol), p-hydroxyphenylaminoacetic acid (Glycin), 1-phenyl-3-pyrazolidone (Phenidone), and many others. Combinations of Metol-hydroquinone and Phenidone-hydroquinone are the most common developing agent formulations used in contemporary black-and-white photography.

The *accelerator* is an alkaline agent, which increases developer agent activity and considerably reduces development times, compared to developing agents used without an accelerator. The pH of the developer is controlled by the chemical used as the accelerator: the higher the pH, the more active the developer becomes. One reason for this is that alkaline solutions swell the gelatin emulsion more than acidic or neutral solutions, allowing for more rapid absorption of the developer solution. This, in turn, enables the reducing agent (developer) to act on the silver halides more rapidly. Typical accelerators in order of increasing activity are borax, sodium carbonate, and sodium hydroxide.

The *preservative* is used to combat aerial oxidation. The developing agent turns brown when mixed with water, loses activity, and may stain print emulsions in a short period of time. This is caused by the rapid depletion of the developing agent, which readily combines with oxygen in the solution. To control this reaction, an inhibitor or anti-oxidant such as sodium sulfite is added to the developer. Sodium sulfite also acts as a solvent for silver halides and thus assists in the action of the developing agents (Sturge, 1977). Ascorbic acid or potassium metabisulfite are used as anti-oxidants, although less frequently (Langford, 1986).

The *restrainer* does not significantly restrain the action of the developing agent, but rather improves its selectivity. Without it, developing agents would start reducing unexposed silver halides, resulting in fogging, which would be particularly noticeable in low-density areas. Fast-acting developers are more likely to reduce unexposed silver during the time required for normal development and therefore require the use of a restrainer. Restrainers generally consist of a soluble halide, such as potassium bromide.

Sequestering agents are also present in commercial developer formulations (Lee, 1984). These prevent the formation of calcium deposits, precipitates, and scales on equipment and film. Manufacturers include this ingredient so that any available water may be used to mix the developer. This problem is avoided by using distilled or deionized water when mixing developers from formulas. Chemicals such as polyphosphate and the polymeric form of sodium hexametaphosphate (Calgon®) and amino acids are commonly used (Lee, 1984).

In this experiment, each component is selectively removed from a published developer formula. The formula used here is for the all-purpose film and paper developer D-72, which is similar to the proprietary developer "Dektol."

Materials and Apparatus

- black-and-white fibre-base photo paper, 8" × 10", single weight
- stop bath
- Kodak Hypo Clearing Agent
- Ilford Hypam fixer
- Kodak Elon developing agent, 15 grams
- Kodak sodium sulfite (anhydrous), 225 grams
- Kodak hydroquinone, 60 grams
- Kodak sodium carbonate (monohydrated), 400 grams
- Kodak potassium bromide (anhydrous), 10 grams
- supplied 8" × 10" master negative (image must contain a photograph and step tablet)
- contact printing frame
- enlarger
- timer
- 4 processing trays, 8" × 10"
- print washer
- reflection and transmission densitometers
- prepared Kodak Curve Plotting Graph Paper

Procedure

1. Prepare 500 mL of a stock solution of D-72, using distilled water and the following formula:

Distilled water (50°C)	500 mL
Kodak Elon developing agent	3.0 grams
Kodak sodium sulfite (anhydrous)	45.0 grams
Kodak hydroquinone	12.0 grams
Kodak sodium carbonate (monohydrated)	80.0 grams
Kodak potassium bromide (anhydrous)	2.0 grams
Distilled water to make	1 liter

2. Prepare five more 500 mL solutions of D-72, omitting one of the five components of the developer in each of the solutions: one solution minus Kodak Elon developing agent, one minus sodium sulfite, etc.

3. Dilute each of the stock solutions from parts 1 and 2 in a ratio of 1:2, using distilled water. Label each solution.

4. Using the contact printer and by trial and error, establish for the master negative the exposure and paper grade which produces a print of good quality. Chapter 6 discusses sensitometric printing methods, which are beyond the scope of this experiment. Expose six prints using the established exposure. Label each sample.

5. Process one master negative print in the 1:2 dilution of "normal" D-72 solution, using the paper manufacturer's recommended development time and standard agitation throughout: stop bath, 15 seconds; two fixing baths, 5 minutes each; wash, 5 minutes; hypo clearing agent, 2 minutes; and wash, 20 minutes.

6. Process the remaining five prints in each of the five other solutions, following the procedure above.

7. Place the prints emulsion side down on drying screens. When dry, measure and record the tricolor and visual densities of each of the print samples.

8. On a single sheet of prepared Kodak Curve Plotting Graph Paper, plot the visual densities of each of the six print samples.

Analysis

Prepare a report in which you discuss the effect of omitting each of the five developer components from D-72.

Question

1. Why is the effect of removing hydroquinone, a developing agent, different from removing Elon, also a developing agent?

4.3.4 Experiment 9: Effect of Various Developers on Film and Paper

Purpose

To examine the effect of three different film developers on one film emulsion, and three different paper developers on one paper emulsion.

Introduction

The alkalinity of a developer affects the rate of development. A highly alkaline solution such as Kodak D-8 developer, used in the graphic arts industry for lithographs, screened images, and high-contrast line-copy negatives and positives, is much more active than lower alkaline solutions such as D-72, Microdol-X, HC-110, or Amidol, which are used for continuous-tone pictorial and scientific photographs.

This experiment is designed to demonstrate the relative activity and the effects of over- and underdevelopment of three different commercially prepared film developers on a single film type. HC-110 (Dilution B) will serve as a standard against which to measure the effects of a high-alkaline developer (D-11) and a slower-acting developer (Polydol). For comparison, three different paper developers will be used on a single paper type and resulting shifts in black-and-white image tone will be measured.

Materials and Apparatus

- Kodak Plus-X Pan Professional Film, 4" × 5"
- Kodak Kodabromide Paper, 8" × 10"
- prepared Kodak Curve Plotting Graph Paper
- Kodak film developers:
  - Polydol, 500 mL
  - HC-110 (Dilution B), 500 mL
  - D-11, 500 mL
- Chemicals to mix paper developers:
  - Dupont 54-D, 1 liter
  - Kodak D-72, 1 liter
  - Agfa 123, 1 liter
  - (see Part II for formulas)
- stop bath
- Kodak Hypo Clearing Agent
- fixer
- Kodak Photo-Flo
- 6 processing trays, 5" × 7"
- 6 processing trays, 8" × 10"
- print washer
- exposure template from Experiment 1
- supplied 8" × 10" master negative
- NuArc point light source
- condenser enlarger
- contact printing frame
- reflection and transmission densitometers

Part I — Film: Procedure

1. Prepare 500 mL of each of the following film developers: Kodak Polydol, Kodak HC-110 (Dilution B), and Kodak D-11.
2. *In total darkness*, expose a film sample (the first of 16 samples) by contact printing the exposure template from Experiment 1 under the point light source. (Use the exposure time and intensities from Experiment 4 — intensity 3 for five seconds, with 1.30 neutral density filtration — as a starting point.) Process the sample in HC-110 (Dilution B) for the recommended time (five minutes at 20°C). If the sample has a gamma of at least 0.50 and no more than two steps of the imaged step tablet are equal to the "base plus fog" of the film, proceed with this exposure time for all samples. If necessary, expose more samples, increasing both development and exposure times.
3. Expose the remaining 15 samples under the point light source, using the exposure determined in step 2. Label each sample after exposure, and place in a film or paper safe.
4. Processing is to be carried out in 5" x 7" trays, following the procedure outlined in ANSI Standard PH4.29-1986. Have ready trays and solutions for stop bath (30 seconds), two-bath fixer (five minutes each), wash (five minutes), hypo clearing agent (two minutes), final wash (10 minutes) and photo-flo (30 seconds). Hang film samples to dry after processing.
5. Process three labelled film samples in HC-110 (Dilution B) for the recommended time.
6. Process three film samples in Polydol developer for the manufacturer's recommended time. Process three more film samples in Polydol developer for the same time used to develop the HC-110 samples above.
7. Process three film samples in D-11 developer for the manufacturer's recommended development time. Process three more film samples in D-11 for the same time used to develop the samples in HC-110 above.
8. When all the samples are dry, measure and record tricolor and neutral density readings for each sample.
9. Average the readings from each set of three samples developed by the five different developer/time combinations given above. For example, average each step wedge's readings for the three samples developed in Polydol at the recommended time; average each step wedge's readings for the three samples developed in Polydol for the HC-110 development time, etc.
10. Each of the five developer/time combinations will require four sheets of graph paper: one for neutral density and one for each of three color readings. (Note that the HC-110 five-minute sample is used for comparison throughout.) Group the curves as follows:

("m.r.t." = manufacturer's recommended time)

Graph 1	1 curve for Polydol (m.r.t.)	neutral densities
Graph 1	1 curve for D-11 (m.r.t.)	neutral densities
Graph 1	1 curve for HC-110 (5 minutes)	neutral densities
Graph 2	1 curve for Polydol (m.r.t.)	red densities
Graph 2	1 curve for D-11 (m.r.t.)	red densities
Graph 2	1 curve for HC-110 (5 minutes)	red densities
Graph 3	1 curve for Polydol (m.r.t.)	green densities
Graph 3	1 curve for D-11 (m.r.t.)	green densities
Graph 3	1 curve for HC-110 (5 minutes)	green densities
Graph 4	1 curve for Polydol (m.r.t.)	blue densities
Graph 4	1 curve for D-11 (m.r.t.)	blue densities
Graph 4	1 curve for HC-110 (5 minutes)	blue densities

(The next four graphs compare the five-minute development times for Polydol and D-11 to the HC-110 norm.)

Graph 5	1 curve for Polydol (5 minutes)	neutral densities
Graph 5	1 curve for D-11 (5 minutes)	neutral densities
Graph 5	1 curve for HC-110 (5 minutes)	neutral densities
Graph 6	1 curve for Polydol (5 minutes)	red densities
Graph 6	1 curve for D-11 (5 minutes)	red densities
Graph 6	1 curve for HC-110 (5 minutes)	red densities
Graph 7	1 curve for Polydol (5 minutes)	green densities
Graph 7	1 curve for D-11 (5 minutes)	green densities
Graph 7	1 curve for HC-110 (5 minutes)	green densities
Graph 8	1 curve for Polydol (5 minutes)	blue densities
Graph 8	1 curve for D-11 (5 minutes)	blue densities
Graph 8	1 curve for HC-110 (5 minutes)	blue densities

Analysis

Write a report describing the effects of each of the three developers on a single film type, Kodak Plus-X Pan Professional Film.

Questions

1. D-11 normally has a very short development time. What effect has the extended development time had on the film?

2. What effect has a reduced development time had on the film in the case of Polydol, which normally has a relatively long development time?

Part II — Paper: Procedure

1. Prepare the following three developer solutions:

Cold-Tone Developer — Dupont 54-D

Distilled water (50°C)	750.0 mL
Metol	2.7 grams
Sodium sulfite, desiccated	40.0 grams
Hydroquinone	10.6 grams
Sodium carbonate, anhydrous	75.0 grams
Potassium bromide	0.8 gram
Distilled water to make	1.0 liter

Medium-Tone Developer — D-72

Distilled water (50°C)	500.0 mL
Elon developing agent (Metol)	3.0 grams
Sodium sulfite (desiccated)	45.0 grams
Hydroquinone	12.0 grams
Potassium carbonate (monohydrated)	80.0 grams
Potassium bromide (anhydrous)	2.0 grams
Distilled water to make	1.0 liter

Warm-Tone Developer — Agfa 123

Distilled water (50°C)	750.0 mL
Sodium sulfite (desiccated)	60.0 grams
Hydroquinone	24.0 grams
Potassium carbonate	80.0 grams
Potassium bromide	25.0 grams
Distilled water to make	1.0 liter

2. Place the enlarger head at its maximum height and unfocus the lens. Using an exposure meter, check the evenness of illumination. Adjust the enlarger height if necessary to achieve even illumination. Make a test sample using Kodak Kodabromide Paper (a medium-tone paper). Expose the paper in contact with the 8" × 10" negative, for 10 seconds.

3. Develop the sample in the medium-tone developer (D-72) for two minutes. Adjust the exposure and repeat processing samples until the grey scale shows at least two steps of "base plus fog" (blocked whites) and two steps of D-max (maximum black).

4. Using the exposure time established in step 3, expose five 8" × 10" sheets of Kodabromide paper in contact with the 8" × 10" master negative. Label these five samples.

5. Develop two sheets of paper in Dupont 54-D (cold-tone developer): one sheet for three minutes; one sheet for the paper manufacturer's recommended time (two minutes). Follow the subsequent processing procedures outlined in ANSI Standard PH4.29-1986.

6. Develop two sheets of paper in Agfa 123 (warm-tone developer): one sheet for 3 $^{1}/_{2}$ minutes; one sheet for the paper manufacturer's recommended time of two minutes. Complete the processing of these samples as above.

7. Develop one sheet of paper in D-72 (medium-tone developer) for two minutes, the manufacturer's recommended development time. Complete the processing of the D-72 sample.

8. Record the tricolor and neutral densities for all samples.

9. Using the same kind of grouping applied for film samples in Part I, plot the three curves per sheet on prepared Kodak Curve Plotting Graph Paper for each of the three developer types:

Graphs 1 – 4:
    neutral, red, blue, and green densities
    for *manufacturer's recommended time*:

    Dupont 54-D
    D-72
    Agfa 123

Graphs 5 – 8:
    neutral, red, blue, and green densities
    for *two-minute development*:

    Dupont 54-D
    D-72
    Agfa 123

The two-minute development time for D-72 should appear on all graphs, as a standard for comparison.

Analysis

Write a report that describes and analyses the effects of normal, extended, and shortened development time in each of the three paper developers.

Questions

1. What accounts for the shift in image tone (color) among samples?

2. Is there any correlation between image color and characteristic curve among the paper developers tested?

4.3.5 Experiment 10: Effect of Fixing Times on Film — Density Changes

Purpose

To demonstrate the effect of fixing time on the image silver and silver halide components of the photographic emulsion.

Introduction

The fixer (sodium or ammonium thiosulfate) converts the unexposed silver halides to soluble silver complexes that can be removed by washing. This renders the photograph insensitive to light. The sodium thiosulfate not only converts silver halides into soluble complexes, but also will act on the image-forming metallic silver to bring about a reduction in the density of the image (see Chapter 8).

The fixer is available in several formulae, plain, non-hardening sodium thiosulfate (hypo), acid fixer, acid hardening fixer, and rapid fixer (usually an ammonium thiosulfate formulation, which often includes a hardener).

Each of these formulations affects the silver gelatin emulsions in different ways. The plain fixer converts the silver halide crystals into soluble silver thiosulfate complexes that can be washed away quite easily. The acid in the fixer prevents excessive swelling of the gelatin emulsion and neutralizes any developer that may be carried over into the fixing bath. This reduces the risk of the formation of dichroic fog, which results from silver oxidation due to contaminated fixer. The hardener in the fixer, such as potassium alum, combines with the gelatin to harden it and increases the abrasion resistance of the gelatin, making the surface of the film or paper able to withstand further aqueous treatments and handling. The rapid fixers contain ammonium thiosulfate rather than sodium thiosulfate. They reduce fixing times considerably, particularly with silver bromide emulsions on resin-coated papers. Reduced fixing times permit high-speed processing of films and reduced immersion times for fibre-base and resin-coated photographic papers. This, in turn, reduces the degree of absorption of thiosulfates into the paper base, permitting shorter wash times and easier removal of residual thiosulfate complexes, which increases the photograph's long-term stability.

Materials and Apparatus

- 18 strips of Kodak Plus-X Pan 35-mm Film (bulk), each 6"
- Kodak fixer, 3 liters
- stop bath, 1 liter — pH 3.5 minimum
- hypo clearing agent — 1 liter
- exposure template from Experiment 1
- prepared Kodak Curve Plotting Graph Paper
- contact printing frame
- timer
- NuArc point light source with 1.30 neutral density
- Hope 152 Black-and-White Film Processor
- rocker table
- 8" × 10" trays
- transmission densitometer

Procedure

1. *In total darkness*, using the point light source at intensity 3 with 1.30 neutral density filtration, contact print the exposure template from Experiment 1 with each of the 18 film samples in exactly the same manner. Exposure time should be five seconds. Label each sample and place all in a paper safe.
2. Remove the roller transport mechanism from the fixing tank of the Hope 152 Black-and-White Film Processor.
3. Develop three film samples in the processor at 50% base speed. In total darkness, take the film samples directly from the developing bath and place them in the stop bath tray for a minimum of 30 seconds.
4. Place the three samples in the fresh fixing bath tray, which has been placed on the rocker table for continuous agitation. Maintain total darkness for the first two minutes. Continue fixing these three samples for two hours.
5. Repeat the processing steps above for each set of three samples, varying the fixing times:

   3 samples — 60 minutes in a fresh fixing bath
   3 samples — 30 minutes in a fresh fixing bath
   3 samples — 15 minutes in a fresh fixing bath
   3 samples — 5 minutes in a fresh fixing bath
   3 samples — 2 minutes in a fresh fixing bath

6. When the fixing is complete for each set of three samples, wash the samples for 10 minutes, place in a hypo clearing bath for two minutes (with agitation), and wash again for five minutes. Dry all the samples.
7. Take neutral transmission density readings of each step of each sample's step wedge. Determine the average reading for each step on the step wedge within each group of three samples. On a single sheet of prepared Kodak Curve Plotting Graph Paper, plot the average characteristic curve for each of the six different fixing times.

Analysis

Write a report that describes the effect of prolonged fixing times on film density.

Question

1. How does the fixing bath reduce the image-forming metallic silver?

4.3.6 Experiment 11: Effect of pH Levels on Developer and Fixer Activity — Silver Densitometric Method

Purpose

To determine the effect of developer pH and fixer pH on film processing.

Introduction

The pH of a solution is defined as the negative logarithm of the hydrogen ion (H+) concentration in gram equivalents or moles per liter of solution. Acidic solutions range from 0 to 7.0 pH; alkaline solutions range from 7.0 to 14.0 pH; a pH of 7.0 is considered neutral. The pH of ordinary tap water is rarely neutral, but varies from city to city, which affects the activity of processing chemicals mixed in tap water.

The pH of the photographic developer determines the activity level of the developing agent. This, in turn, affects the rate of development, the resultant grain structure, the gamma, and the degree of swelling and de-swelling of the gelatin that occurs during processing. This experiment will examine some of these effects.

Alkaline buffers are added to developing solutions to maintain developing agents at their optimum or desired activity. Alkalis are also added to neutralize the acidic by-products of the reduction of metallic silver which, if allowed to build up, could lower the pH of the solution and slow the rate of reaction.

The pH of most photographic gelatins is in the range of 4.7 to 5.2 (Haist, 1979). In aqueous solutions, gelatin will swell, particularly if the temperature is elevated; gelatin becomes soluble at 40°C (James, 1977). It will also swell in the presence of alkalis. The swelling of the gelatin during processing allows the chemicals to more easily penetrate and make contact with the silver halide crystals. Part I of this experiment deals with the effect of changing the pH of the developer.

The pH of the sodium or ammonium thiosulfate fixing solutions also regulates the rate of gelatin de-swelling. By taking a film sample from an alkaline developer and placing it first in an acid stop bath and then in a fixing bath, the development action is halted and the gelatin is de-swelled. In addition, those hardening fixers that contain alum hardeners require moderate acidity to be effective in hardening the gelatin. Part II of this experiment will deal with the effect of changing the pH of an acid hardening fixing bath on the rate and degree of fixing. Swellmeter testing also will be carried out on these samples at a later point in the study guide.

Materials and Apparatus

- Kodak Tri-X or Plus-X Pan Professional Film, 50 sheets, 4" × 5"
- Kodak D-76 developer components:
    - sodium sulfite (anhydrous), 150 grams
    - metol, 3 grams
    - hydroquinone, 7.5 grams
    - borax (granular), 4 grams
    - distilled water
- Kodak HC-110 developer
- Kodak Indicator Stop Bath
- glacial acetic acid
- ammonium hydroxide
- Kodak fixer
- ANSI fixer components:
    - sodium thiosulfate (pentahydrated)
    - sodium sulfite
    - distilled water
- Silver Densitometric Method Reagents:
    - silver nitrate
    - acetic acid
    - sodium chloride
    - sodium thiosulfate
    - sodium sulfite
- Kodak Photo-Flo
- Kodak Process Control Sensitometer, Model 101
- transmission densitometer with Status M filters
- NuArc point light source
- contact printing frame
- exposure template from Experiment 1
- prepared Kodak Curve Plotting Graph Paper
- neutral density filters, 3" × 3"
- processing trays, 5" × 7"
- timer
- latex gloves
- pH meter
- print washer

Part I — Developer pH: Procedure

1. Place the exposure template from Experiment 1 (emulsion facing out) on the outside surface of the exposure plane of the Kodak Process Control Sensitometer. This will ensure good contact with the film.

2. Place the maximum dichroic filtration (1.94) in the appropriate stop in the sensitometer. Further filtration will be required. Place neutral density filters in the color filter holder in the sensitometer. If using Tri-X Film, approximately 0.60 additional density should be sufficient. Test exposures should be taken if using Plus-X with no extra neutral density filters beyond the dichroic filter.

3. Mix three solutions of D-76 developer:

    a. Distilled water (50°C) 375 mL

Distilled water (50°C)	375 mL
Kodak Elon developing agent	1 gram
Sodium sulfite (anhydrous)	50 grams
Hydroquinone	2.5 grams
Borax (granular)	1 gram
Distilled water to make	500 mL

    b. Omit Borax from the D-76 formula.

    c. Increase Borax in the D-76 formula to 3 grams.

4. Prepare standard stop bath, fixing bath, and hypo clearing bath.
5. Using the sensitometer, contact print the exposure modulator to one film sample. Process the sample according to suggested manufacturer's times. (If Tri-X is used, development time is 9 1/4 minutes at 20°C.) Develop the sample in the standard D-76 solution. When processing is complete and the film is dry, take density readings from the step wedge and plot the characteristic curve. If the gamma is close to 1.0 and no greater than two steps are equal to "base plus fog", proceed with the experiment. If not, add or subtract neutral density filters as required and expose another test sample.
6. Once the correct exposure has been determined, expose all 24 film samples. Label each sample.
7. Process eight samples in the full D-76 formula, eight in the solution without Borax, and eight in the solution with extra Borax. In each of the three D-76 solutions, vary the development time for the eight samples:

Sample 1:	30 seconds
Sample 2:	1 minute
Sample 3:	2 minutes
Sample 4:	4 minutes
Sample 5:	6 minutes
Sample 6:	8 minutes
Sample 7:	10 minutes
Sample 8:	12 minutes

8. Complete the processing through the stop bath (30 seconds), fixing bath (two 5-minute baths of Kodak fixer), and hypo clearing bath (two minutes), agitating throughout. Wash the samples for 10 minutes, rinse with Kodak Photo-Flo, and hang to dry.
9. Using the transmission densitometer, take neutral density readings of all the steps on every sample.
10. Use eight sheets of prepared Kodak Curve Plotting Graph Paper, one for each of the eight development times. On each of the eight development time sheets, combine the curves for each of the three D-76 developer formulas.
11. Retain these 24 samples for swellmeter testing, which will be carried out at a later point in the study guide.

Part II — Fixer pH — Silver Densitometric Method: Procedure

1. Mix one liter of ANSI fixing bath, using the following formula:

Distilled water	600 mL
Sodium thiosulfate, pentahydrated	250 grams
Sodium sulfite	20 grams
Distilled water to make	1 liter

2. Mix two more liters using this formula. To 1 liter, add approximately 4 mL of glacial acetic acid. To another liter, add approximately 4 mL of ammonium hydroxide (28%).

3. Measure the pH of the three fixing solutions, and label them. The fixer with acetic acid should measure approximately pH 6.6. The fixer with ammonium hydroxide should measure approximately pH 11.0. The standard ANSI fixing bath should measure approximately pH 9.7.

4. To determine the effect of pH on the rate of fixing, a number of samples will be fixed for times ranging from five seconds to three minutes. Use seven film samples (half sheets of 4" × 5" film) for each of the three fixing solutions. Label samples.

5. Prepare one liter of film developer (HC-110, Dilution B) and stop bath (Kodak Indicator Stop Bath).

6. Working in complete darkness, place each of 21 unexposed film samples in the developer for three minutes, and then in the stop bath for 30 seconds.

7. Fix seven of the developed film samples in each of the three ANSI fixer solutions, for the following times:

Sample 1:	5 seconds
Sample 2:	10 seconds
Sample 3:	15 seconds
Sample 4:	30 seconds
Sample 5:	1 minute
Sample 6:	2 minutes
Sample 7:	3 minutes

8. Wash the samples for one minute in an archival print washer. Treat in a hypo clearing bath for two minutes. Wash for five minutes. Rinse the samples in a photo-flo bath for 30 seconds and hang to dry.

9. Prepare solutions for the Silver Densitometric Method as outlined in ANSI Standard PH4.8-1985, *Residual Thiosulfate and Other Chemicals in Films, Plates and Papers: Determination and Measurement.* All test reagents should be made up using distilled or de-ionized water.

   Reagent No. 1: Silver nitrate-acetic acid. Dissolve 10 grams of silver nitrate in a solution containing 30 mL glacial acetic acid in 750 mL water. Dilute to one liter and store in a stoppered brown glass bottle.

   Reagent No. 2: Sodium chloride. Dissolve 50 grams of sodium chloride in 500 mL of water. Dilute to one liter.

Reagent No. 3: Sodium thiosulfate-sodium sulfite. Dissolve 19 grams of sodium sulfite and 50 grams of sodium thiosulfate pentahydrate in 750 mL of freshly boiled and cooled distilled water. Dilute to one liter.

10. Cut a 1.5 cm × 6 cm strip from each of the 21 processed film samples produced above (Part II, step 7). Label each strip. Fold each strip in half lengthwise with the emulsion side out.

11. Immerse half of the strip folded end down in 20 mL of silver nitrate-acetic acid reagent for four minutes, agitating occasionally. Drain off excess reagent.

12. Immerse the entire strip in 20 mL of the sodium chloride reagent for four minutes with occasional agitation. Drain off excess reagent.

13. Immerse the entire strip in 20 mL of the sodium thiosulfate-sodium sulfite reagent for four minutes agitating occasionally. Drain off excess reagent.

14. Wash the sample strip under running tap water for 5 to 10 minutes. Hang to dry. Repeat this procedure for each of the 21 sample strips.

15. Refold each dry strip with the emulsion out. Measure and record the density of the stained areas using a Kodak No. 18A filter (with a densitometer that uses a photomultiplier tube as the detector), following the procedure outlined in ANSI Standard PH4.8-1985. Record the density of the unstained areas. Determine the density difference (ΔD) by subtracting the unstained densities from the stained densities. The greater the ΔD, the less effective the fixation.

Analysis

Write a report analysing the results of the silver densitometric test.

Questions

1. Is film resolution affected by the pH of the developer?

2. What causes the stain on the film strips tested in Part II?

4.4 Scene Reproduction and Tone Control — Introduction

In this section we will begin to learn the techniques for selecting the right film material and controlling the processing sequence, which will be of use later when copying or duplicating photographs.

4.4.1 Experiment 12: Even Density on Paper and Film Samples

Purpose

To expose and process film and paper samples so as to obtain as even density as possible.

Introduction

Since the invention of photography, scientists, photographers, and technicians have been seeking the ideal system for producing a consistent and even density on sheets and rolls of photographic materials.

The complex nature of the photographic system compounds the flaws of uneven illumination from light sources and enlargers. Optical systems, camera bellows systems, and uneven development through inefficient agitation methods are contributing factors. With care, the illumination can be controlled and monitored, and agitation methods can be improved and modified. More than 50 years ago, J. I. Crabtree noted that moving the film through the chemicals at an even rate, rather than moving the chemicals over the film, provides an efficient method for maintaining even development over the surface area of the print or film. Roller transport machines, such as the Hope 152 Black-and-White Film Processor in use in the Photograph Conservation Laboratory, have been employed in many photographic processing situations, providing a high degree of uniformity in the agitation during development. This experiment will demonstrate how to achieve uniform density by manual processing. It is designed more than anything to provide for the development, through trial and error, of a good manual processing technique.

Materials and Apparatus

Part I and Part III

- Kodak Ektapan Film #4162, 4 sheets, 4" × 5"
- Kodak HC-110 film developer, Dilution B, 500 mL
- Kodak Indicator Stop Bath
- Kodak fixer, 1 liter
- 6 trays, 5" × 7"
- diffusion enlarger, 4" × 5"
- condenser enlarger, 4" × 5"
- film holders, 4" × 5"
- glass film support, 5" × 7"
- wooden block for supporting film holder
- footcandle meter
- Hope 152 Black-and-White Film Processor
- Kodak Hypo Clearing Agent
- Kodak Photo-Flo solution

Part II

- Ilford Ilfobrom Galerie, Grade 2.1K or higher, 2 sheets of paper, 8" × 10"
- developer (D-72)
- stop bath
- Ilford Hypam fixer
- Ilford Galerie Washaid
- trays, 8" × 10"
- incident light meter or footcandle meter
- archival print washer
- printing easel

Part I — Film Sample — Manual Processing: Procedure

1. Before attempting to expose the negative material, measure the evenness of illumination of the enlarger. Place the diffusion enlarger head at the top of the column, open up the lens aperture, and unfocus the lens. This should provide a large area of even illumination. Pass an incident light meter or footcandle meter across the exposure plane, watching for any fluctuations. Mark off the most even region, using tape on the enlarger base so that the film can be correctly placed for exposure.

2. *In total darkness*, load the film into a film holder. Place the holder in the wooden support and set it in the region of even illumination on the enlarger base. Determining the correct exposure time requires some experimentation. Very short exposure times are difficult to accurately reproduce; extended exposure times may result in too great a density to reveal areas of unevenness. Consequently, neutral density filters may have to be placed over the enlarger lens. The density of the developed film should fall at one point between 1.00 and 1.50, and should "ideally" vary by no more than ± 0.02 at any area on the film.

3. Take the exposed film and tape it emulsion side away from the glass to the center of a piece of glass using small strips of masking tape on the film ends. The glass support should remain stationary in the bottom of a 5" × 7" processing tray. Pour the developer into the tray, then slide in the glass. Agitation should be continuous, raising the three sides of the tray in turn at approximately 2 second intervals, as described in ANSI Standard PH4.29-1986. Using HC-110 (Dilution B) at 20°C, develop for 4 1/2 minutes.

4. Following development, place the glass with the film still attached into a stop bath for 30 seconds, with agitation. (The pH of the stop bath must not be lower than 3.5.) At this time, the film can be removed from the glass plate and placed in the fixing bath. Fixing should be done in two 5-minute baths, with intermittent agitation, 10 seconds every minute. Wash the film for 5 minutes, place in the hypo clearing agent for 2 minutes with agitation, and wash again for 10 minutes. Rinse with diluted photo-flo solution for 15 seconds, and hang to dry.

5. Using a transmission densitometer, take neutral density readings across the entire surface of the film near each edge and in the center of the film. Ideally, densities should vary no more than ± 0.02, for a total range of 0.04 units. If the density range is greater than this, it is worth repeating the manual processing exercise at least once, attempting to be more consistent with agitation during development. Additionally, try re-metering the light source and/or extending the exposure time.

Part II — Paper Sample — Manual Processing: Procedure

1. Place the final film sample in the negative carrier of the diffusion enlarger. Place the glass negative carrier in the enlarger. Open the aperture, unfocus the lens, and raise the column to its full height. Test the evenness of illumination by passing an incident light meter or footcandle meter across the exposure plane.

2. Place an 8" × 10" sheet of photographic paper in an enlarging easel and expose it for 10 seconds (as a beginning point). Develop it in an 8" × 10" processing tray, using the exact procedure outlined in ANSI Standard PH4.29-1986. Ilford Galerie paper developed in D-72 (1:2) requires a 2 minute development.

3. Place the print in the stop bath for 15 seconds with agitation, and then in the Ilford Hypam fixing bath for 30 seconds with agitation. Wash the print for 5 minutes, place it in the Ilford Galerie Washaid for 10 minutes with agitation, and wash again for 5 minutes. Squeegee the excess water from the print and lay it emulsion side down on a drying screen until dry.

4. Measure the visual density across the entire surface of the paper, using a reflection densitometer with Status A filters. The density should be 0.80 ± 0.02. If the density range exceeds 0.04, repeat the experiment, carefully checking every step.

Part III — Roller Transport Processing Method: Procedure

1. Expose a film sample using the procedure outlined in Part I. Process the sample in the Hope 152 Black-and-White Film Processor at 50% base speed. Hang film to dry.

2. Under the condenser enlarger, produce a paper sample with a density of approximately 0.80, using the negative processed in the Hope 152 processor. Process it according to the procedure outlined in Part II.

3. Using the manually processed film sample from Part I above, produce a paper sample with a density of approximately 0.80, using

the condenser enlarger. Process it using the procedure outlined in Part II.

4. Take and record visual density readings of the film sample processed in the Hope 152 processor and the two paper samples produced under Part III.

Analysis

Prepare a report that describes and explains any differences in the evenness of density among the various samples produced above.

Questions

1. Of the processing methods used, which produces the most even density across a sheet of film and paper?
2. How is even illumination best achieved?
3. Describe other variables that may contribute to uneven density.
4. What effect on the evenness of the prints did the negatives have?

4.4.2 Experiment 13: Effect of Film Type on Scene Reproduction

Purpose

To determine the way various film types reproduce a scene of a particular density and tonal range.

Introduction

The photographic industry produces many different black-and-white film emulsions, each having inherent characteristics that make it possible to reproduce the same scene in a variety of tonal ranges and grain structures.

These different films are designed for specific purposes, from general continuous-tone, image-recording materials, to high-contrast, line-copy films. General purpose films are of a low to medium gamma (0.50 to 1.0) and are used for commercial and scientific purposes. Medium-gamma films (0.90 to 1.50) are used for tone reproduction and copying purposes. High-gamma films (1.50 and up) are used for line-copy work as well as for making half-tone screened images in the graphic arts industry. These major film-type groups (and their sub-groups) include emulsions that vary in grain size and shape.

This experiment will use films from each group and examine how they reproduce the same scene. Exposure and development will be carried out according to the manufacturer's recommendations for each film. Kodak Contrast Process Ortho Film #4154, Kodak Ektapan Film #4162, Kodak

Separation Negative Film, Type 1, #4131, and Kodak Kodalith Ortho Film, Type 3, #4556 will be compared in this experiment.

Materials and Apparatus

- Kodak Contrast Process Ortho Film #4154, 4" × 5"
- Kodak Separation Negative Film, Type 1, #4131, cut to 4" × 5"
- Kodak Ektapan Film #4162, 4" × 5"
- Kodak Kodalith Ortho Film, Type 3, #4556, 4" × 5"
- film holders, 4" × 5"
- Kodak Q-14 gray scale
- Kodak Q-14 Color Separation Guide
- RIT Alphanumeric Resolution Positive Reflection Target, 2"
- Kodak D-11 developer, 1 liter
- Kodak HC-110 film developer, Dilution B,1 liter
- stop bath, 500 mL
- Kodak fixer, 1 liter
- Kodak Hypo Clearing Agent, 1 liter
- trays, 5" × 7"
- Sinar 4" × 5" camera
- light meter
- footcandle meter
- transmission densitometer
- Kodak Curve Plotting Graph Paper

Procedure

1. Prepare one liter of each of the following solutions:

   Kodak HC-110 developer (Dilution B)
   Kodak D-11 developer
   stop bath (500 mL)
   Kodak fixer
   Kodak Hypo Clearing Agent

2. Load the film into the film holders and set up the view camera and "scene" (grey scale and alphanumeric resolution target) to be photographed. The grey scale steps must be large enough on the negative to be read on the densitometer using the 3-mm aperture, and so the whole scale should measure approximately 7.0 cm in the camera viewfinder. The resolution target must be small enough so that at least the last numbered series is unrecognizable. Place two flood lamps at either side of and 45° to the scene plane. Measure and record the illumination of the scene using a footcandle meter.

3. Using a standard photographic light meter, determine the correct shutter speed and f-stop for each of the film types. Meter the ANSI speed designations for the ortho films as if they were equivalent to ISO ratings.

4. Expose each of the film types using the estimated exposure settings. Expose a second sheet of each film type, using one stop more exposure. Label these samples.

5. Develop the films in the recommended developers for the manufacturer's recommended time:

Kodak Contrast Process Ortho Film #4154:	D-11	4 minutes at 20°C.
Kodak Ektapan Film #4162:	HC-110 (Dilution B)	5 minutes at 20°C.
Kodak Separation Negative Film, Type 1, #4131:	HC-110 (Dilution B)	6 minutes at 20°C.
Kodak Kodalith Ortho Film, Type 3, #4556:	D-11	3 minutes at 20°C.

Tray process the films using the procedure outlined in ANSI Standard PH4.29-1986.

6. With regular agitation throughout, put the films through a stop bath (30 seconds), two-bath fixer (5 minutes each), wash (10 minutes), Kodak Hypo Clearing Agent (2 minutes), and final wash (5 minutes). Rinse in diluted photo-flo solution and hang to dry.

7. Calibrate the Kodak Curve Plotting Graph Paper using the reflection densitometer and the original Q-14 gray scale. Take reflection visual density readings, subtract each step from the one beside it, and place these numbers on the horizontal axis. Make copies of this prepared graph paper for future use.

8. Plot the relative characteristic curves for both exposures for each of the four film types. Ideally, the curve should have a gamma of approximately 1.0, and there should be some indication of the shoulder and toe regions, although some variation is acceptable. If the toe or shoulder regions are exceptionally long for a particular film, adjust the exposure time and expose another sample. (The two ortho films are extremely high-contrast and it is unlikely that many grey scale steps will fall on the straight-line section of the curve under normal exposure and processing.)

9. When the correct exposure has been determined for each film type, plot the relative characteristic curves of these final film samples on a single sheet of prepared Kodak Curve Plotting Graph Paper.

10. Using the light microscope, measure and record the readable data from the RIT Alphanumeric Resolution target.

Analysis

Prepare a report that evaluates the data collected during this experiment. Discuss these results in terms of each film's appropriateness for reproduction use.

Questions

1. Which film had the highest gamma? Why?
2. How do the resolution characteristics differ for each film processed in this experiment, and why?

4.4.3 Experiment 14: Establishing Processing Controls and Parameters

Purpose

To examine the need for process control parameters in a film processing system, and to establish those controls.

Introduction

The previous experiments have shown how controlling different variables such as exposure, development and later processing can produce desirable results. Film emulsions, the chemical activity of processing solutions, and the mechanical performance of processing systems, however sophisticated, are subject to some degree of variability. The aim of a process monitoring system is to establish parameters within which fluctuations are allowed to occur. These parameters are based on measurements of a number of film samples of the same emulsion type, which are processed individually and at different times. The density values of these test strips (Kodak Process Control Strips) are then averaged. The values are used to establish the allowable variation within the process. This data forms the basis of process monitoring and control methods for film and paper processing.

Process control is used to monitor and provide data that can assist in initiating corrective measures to re-establish processing consistency within replenishment developing systems.

The information gained from determining processing parameters is used to perform a graphic analysis of the process activity on a day-to-day basis. This graph is called a *Process Control Chart.* It consists of a horizontal line that represents the mean; process control limit lines represent limit values that the process should not go beyond. The densities of a particular day's processed test strip are plotted against the mean density value, to show process changes. From the control values initially established, the upward or downward movement of the values indicates a fluctuation in the processing system which must be attended to. Process control monitoring can be assisted by other factors, including measuring the solution activity in terms of its pH. As shown in Experiment 11, pH plays an important role in both the development and fixing of silver gelatin materials. Monitoring the pH on a regular basis can indicate potential problems. Keeping a strict count of negatives or prints processed in a particular solution will give some indication of when the chemicals are approaching exhaustion. This requires prior experience or reliance on the manufacturer's suggestions regarding the quantity of material that can be processed in a set amount of processing solution.

Fixing baths can be tested for exhaustion by the periodic use of a potassium iodide solution, a drop or two of which is added to the fixing bath. When a yellow-white precipitate forms instantly, the fixer is depleted and should be discarded.

This experiment will examine general process monitoring and the use of Kodak Process Control Strips.

Materials and Apparatus

- Kodak Process Control Strips
- Kodak Color Process Record Form No. Y-55
- pH meter
- Hope 152 Black-and-White Film Processor
- transmission densitometer

Part I — Process Control Strips, Fixer Test Solution, and Quantity Monitoring: Procedure

1. Prepare the Hope 152 film processor for use.
2. Read Kodak publication No. Z-128: *Black-and-White Film and Paper Processing and Processing Monitoring*.
3. After labelling each one, process six Kodak Process Control Strips, one at a time, in the Hope 152 processor at 50% base speed. Ensure that the process control strips are processed in exactly the same manner. Any change in the placement of the samples in the processing solutions or in strip orientation will affect the results used to establish and monitor solution activity.
4. Measure and record the high- and low-density patches, using the transmission densitometer with the visual filter. After reading all six process control strips, add all of the density values of the low-density (LD) patches, then divide the sum by the number of strips processed. This is the mean value.
5. Repeat step 4 for the high-density (HD) patches.
6. Subtract the HD mean from the LD mean. This gives a mean density difference (DD), which is an indicator of contrast fluctuation.
7. Following the procedures outlined in Kodak publication No. Z-128, record (on a sheet of Kodak Color Process Record Form No. Y-55) the reference code number from the process control strip itself. On the top horizontal axis, place the mean density difference (DD) value. It is this value against which all other control strips will be measured.

8. The second horizontal axis is for the mean low density (LD) value. All other LD control strip readings will be measured against this value.

9. Deviations from these mean values are acceptable within a set range. For machine processing, the range is ± 0.08. Mark these limits on the process record form, on either side of the horizontal LD and DD axes.

10. Control strips should be run through the machine every day, prior to processing any film, and the results recorded on the Kodak Color Process Record Form. Draw lines between the readings for ease in determining trends.

11. Measure the pH of all the processing solutions and record each on the Kodak Color Process Record Form under the mean DD and LD values. As subsequent control strips are run through the machines, take pH readings and record them on the form below the corresponding control strip density readings.

12. Make up a solution of Kodak Fixer Test Solution FT-1, using the following formula:

Distilled water (26.5°C)	750 mL
Potassium iodide	190 grams
Distilled water to make	1 liter

Test the fixing bath with a few drops of this solution following the processing of control strips.

13. Hang a calendar beside the Hope 152 processor on which to record the number of negatives processed. Every time a piece of film is put through the machine, it should be marked on the calendar, and the numbers totalled at the end of each day.

Analysis

After a month of charting the performance of the film processor, write a brief report on its performance.

Questions

1. Did the control point exceed the control limits and why?

2. Was the pattern made by the control points random or did they indicate any trends?

3. Were any series of points consistently above or consistently below the mean point? If so why?

4. Did the process appear to cycle regularly up and down? If so why?

4.5 Processing for Permanence — Introduction

Silver gelatin photographic materials deteriorate as a result of a combination of factors: cycling temperature and relative humidity, chemical reagents, mechanical damage, and biological damage. Although the photographic image may not last forever, measures can be taken to reduce silver image deterioration and extend the useful life of the photograph.

Atmospheric pollutants, such as sulfur dioxide, will attack the silver image by converting it to yellow silver sulfide. Cycling relative humidity and temperature in conjunction with this and other oxidizing agents, both in the atmosphere and from residual processing chemicals, can adversely affect the image silver, the binding medium, and the support material. Oxidizing agents can convert the image silver to silver ions, which then migrate through the binder and may subsequently create a metallic silver sheen on the surface of the photograph. Silver ions may also combine with sulfur compounds, forming yellow silver sulfide, which appears as image discoloration.

The size of the image silver grains is an important variable in the deterioration of the photograph. The smaller the grain size of the image, the greater the tendency for the silver to decompose or be affected by oxidizing agents. As the grain size of the photographic print is much smaller than the grain size of most negatives, prints have a tendency to deteriorate more rapidly.

The amount of residual chemicals (silver complexes or thiosulfate) in the photographic image has by far the greatest impact on the stability of the silver gelatin image. If a large concentration of either of these chemicals is allowed to remain in the emulsion or support material, the image will quickly exhibit yellow or brown mottled stains.

A major responsibility of the conservator of photographic records is to ensure that contemporary black-and-white materials, in the form of duplicate and copy negatives, and copy photographs produced in-house as surrogates are processed in a way that will maintain image quality over long periods of time.

Understanding the factors that contribute to the permanence of a photographic image can help the photograph conservator determine the causes of image deterioration in those images that were produced elsewhere and later placed in the custody of an archive or library.

4.5.1 Experiment 15: Methods of Processing for Permanence

Purpose

To examine methods of processing black-and-white silver gelatin images on paper for maximum permanence.

Introduction

Among the many processing procedures that have been used since the development of the silver gelatin emulsion, we will consider three methods that adequately remove residual processing chemicals (sodium thiosulfate complexes and silver salts being the major offenders) from photographic materials.

1. *Classical Processing Procedure*

Development (use Kodak Dektol, 1:2):	2 minutes
Kodak Indicator Stop Bath:	30 seconds
First fresh (hardening) fixing bath:	3 to 5 minutes
Second fresh (hardening) fixing bath:	3 to 5 minutes
Rinse:	1 minute
Kodak Hypo Clearing Agent:	2 to 3 minutes
Wash:	20 minutes

The first fixing bath becomes contaminated by carry-over from the preceding steps and the large volume of silver salts removed during the first 3 minutes of fixing. This procedure (with selenium toning, discussed below) has been widely promoted and is used by many serious photographers.

2. *ANSI Standard PH4.32-1986 — Processing Procedure*

Development (use Kodak Dektol, 1:2):	2 minutes
ANSI stop bath:	approximately 10 seconds
First fresh ANSI (non-hardening) fixing bath:	5 minutes
Second fresh ANSI (non-hardening) fixing bath:	5 minutes
Wash:	30 minutes (single weight fibre-base prints)
Air dry	

3. *Ilford Ilfobrom Galerie Processing Procedure*

Development (use Ilford PQ Universal, 1:9):	2 minutes
Ilford In-1 Acid Stop Bath:	30 seconds
Ilford Hypam fixer (1:4):	30 seconds
Wash:	5 minutes
Ilford Galerie Washaid:	10 minutes
Wash:	5 minutes
Air dry	

Because of the short fixing times, less thiosulfate is absorbed into the paper and wash times are significantly reduced.

4. *Selenium Toning*

The use of selenium toner does not constitute a separate method, but is an important after-treatment that is used in conjunction with the three processing procedures outlined above. (The effect of selenium toning on permanence is discussed in Section 4.5.5.) Indeed, the use of selenium toner is increasingly considered an essential part of processing for permanence procedures. Recently,

F. J. Drago and W. E. Lee recommended that Kodak Rapid Selenium Toner, diluted 1:19, be used as a post-processing treatment for negatives that must be subjected to long-term storage under various conditions (Drago, 1984). Other studies by the same authors indicate the effectiveness of selenium toner in a variety of applications (Lee, 1984). The most effective way to enhance image stability is by converting unstable silver compounds to more stable compounds. When used at low concentrations (1:20 or less), selenium toning appears to change the silver structure and color very little while providing a significant increase in stability of the image.

This experiment is designed to make paper and film samples using the three processing procedures listed above, both with and without selenium toner. The samples produced here will be subjected to various tests in Experiment 17 (Test for Residual Silver Salts) and Experiment 18 (Test for Residual Thiosulfates). These experiments are designed to test the effectiveness of processing procedures in removing residual chemicals. Samples will also be made here in Experiment 15 for use in later experiments on accelerated aging, in Chapter 10.

Materials and Apparatus

- Ilford Ilfobrom Galerie paper, 11 sheets, 8" × 10"
- Kodak Tri-X Pan Professional film, 12 sheets, 4" × 5"
- Ilford PQ Universal developer
- Kodak HC-110 film developer, Dilution B
- Kodak Indicator Stop Bath
- Kodak Rapid Fixer
- Kodak fixer
- Ilford Galerie Washaid
- Kodak Hypo Clearing Agent
- ANSI non-hardening fixer
- Kodak Rapid Selenium Toner
- NuArc point light source
- condenser enlarger
- exposure template from Experiment 1

Procedure

Agitation during all processing steps outlined below should follow the procedure outlined in ANSI Standard PH4.29-1986, *Methods for Manual Processing of Black-and-White Photographic Films, Plates, and Papers.*

1. Prepare chemicals for the *Classical Processing Procedure,* including Kodak Dektol paper developer, Kodak Indicator Stop Bath, and Kodak Hypo Clearing Agent. Mix 2 liters of Kodak Fixing Bath F-5, using the following formula:

Distilled water (50°C)	600 mL
Sodium thiosulfate (pentahydrated)	240 grams
Sodium sulfite (anhydrous)	15 grams
Acetic acid (28%)	48 mL
Boric acid (crystals)	7.5 grams
Potassium alum (fine granular, dodecahydrated)	15 grams
Cold distilled water to make	1 liter

2. Read ANSI Standard PH4.32-1986, *Methods for Evaluating Processing with Respect to the Stability of the Resultant Image — Black-and-White Papers*. Prepare chemicals as outlined in this standard. The developer to be used is Ilford PQ Universal paper developer. The stop bath, fix, and hypo clearing solution are prepared according to the following formulas.

   Stop bath

Distilled water	500 mL
Acetic acid (28% solution)	48 mL
or	
Glacial acetic acid	13 mL
Distilled water to make	1 liter

   Fixing bath

Distilled water	600 mL
Sodium thiosulfate (pentahydrate)	250 grams
Sodium sulfite	20 grams
Distilled water to make	1 liter

   Hypo clearing solution

Sodium sulfite (1% solution)	1 liter

3. Prepare chemicals for the *Ilford Ilfobrom Galerie Processing Procedure*, including developer, fix, and washaid, according to manufacturer's recommendations.

4. Prepare *Kodak Rapid Selenium Toner*, diluted 1:19 with distilled water.

5. *Under a safelight*, prepare paper samples. The paper to be used is Ilford Ilfobrom Galerie, 2.1K. Take 11 sheets of the 8" × 10" paper and divide them into quarters, which will yield 44 sample sheets, 4" × 5". Because of the large number of samples used in this experiment, take special care to label all samples clearly.

6. Push the light source of the condenser enlarger to its maximum height on the column until a large portion (80%) of the base is illuminated. Open and unfocus the lens, and measure the evenness of illumination, using a footcandle meter. Using the exposure template from Experiment 1, expose a test print in the contact printing frame under the enlarger. The exposure should be such that the first two or three steps of the grey scale have the same reading. There should be two or three steps of D-min and two or three steps of D-max. (When attempting to establish a correct exposure and development time, use the complete Galerie processing system, as it requires much less time.)

7. Take visual density readings of the final test exposure. Using a sheet of prepared Kodak Curve Plotting Graph Paper, draw its characteristic curve.

8. Prepare to expose and process 12 samples, 4" x 5", using the *Classical Processing Procedure*. Process six of the samples in half of the quantity of each solution. Tone these six samples in Kodak Rapid Selenium Toner (1:19). Use the following additional processing steps:

Selenium Toner:	3 minutes
Wash:	20 minutes
Air dry	

9. Expose and process the other six samples using the *Classical Processing Procedure*. **Do not tone these six samples.**

10. Prepare to expose and process 12 paper samples, 4" x 5", using the *ANSI Processing Procedure*. Expose and process six of the samples in half of the prepared chemicals. Tone these six samples in Kodak Rapid Selenium Toner (1:19). Use the same additional three steps as in step 8 above.

11. Using the *ANSI Processing Procedure*, expose and process the other six samples. **Do not tone these six samples.**

12. Prepare to expose and process 12 paper samples, 4" x 5", using the *Ilford Ilfobrom Galerie Processing Procedure*. Expose and process six of the samples in half of the prepared chemicals, and tone them in Kodak Rapid Selenium Toner (1:19). Add the three additional processing procedures given in step 8 above.

13. Process the remaining six paper samples using the *Ilford Ilfobrom Galerie Processing Procedure*, using fresh developer and fixer solutions. **Do not tone these samples.**

14. *In total darkness*, make test exposures for the film samples, using Kodak Tri-X Pan Professional 4" x 5" Film and the exposure template from Experiment 1. Process the test exposure in Kodak HC-110 (Dilution B) developer for five minutes. (Use the tray processing method outlined in ANSI Standard PH4.29-1986.) When the test sample is dry, read the visual densities and plot the characteristic curve. Aim for a gamma of approximately 1.0.

15. When correct exposure is determined, prepare to expose and process half of the film samples:

HC-110 (Dilution B) developer:	5 minutes
Kodak Indicator Stop Bath:	30 seconds
Kodak Rapid (non-hardening) Fixer:	3 minutes
Wash:	5 minutes
Kodak Hypo Clearing Agent:	2 minutes
Wash:	5 minutes
Kodak Rapid Selenium Toner (1:19):	3 minutes
Wash:	20 minutes
Kodak Photo-Flo:	30 seconds
Air dry	

16. Expose and process the remaining six film samples. **Do not tone them.** Eliminate the additional treatments that follow toning in the procedure outlined in step 15 except substitute a 20-minute wash in place of the 5-minute wash.

17. Place all film and paper samples in Mylar sleeves. The samples will be used in Experiment 17 (Test for Residual Silver Salts) and Experiment 18 (Test for Residual Thiosulfates).

Question

1. Without having carried out tests on the samples, and based on the theory of processing for permanence (as discussed in the Supplemental Readings), which method do you expect will offer the greatest permanence? Why?

4.5.2 Experiment 16: Effect of Fixing Times on Paper — Staining

Purpose

To demonstrate the effect of fixing times on the image silver and silver halide components of the photographic emulsion.

Introduction

In Experiment 10, we observed the effect of prolonged fixing on film density. In this experiment, we shall subject the photographic print emulsion to fixing times ranging from 5 seconds to 30 seconds, using a rapid fixer. Half of the samples will be treated with a sodium sulfide solution, as a means of determining the susceptibility to staining of inadequately fixed prints. Before proceeding with this experiment, review the introduction to Experiment 10.

Materials and Apparatus

- 12 strips of fibre-base silver bromide photo paper, each 1" × 6" (unexposed)
- Ilford Ilfospeed paper fixer mixed 1:3, 400 mL
- 0.2% sodium sulfide solution (in distilled water)
- 3 developing trays, 5" × 7"
- timer
- reflection densitometer

Procedure

1. *Under safelight illumination*, label each paper sample. Immerse six unexposed samples simultaneously, with continuous agitation, in the Ilfospeed fixing solution. Remove one strip at a time, at 5 second intervals. The sixth sample will have had 30 seconds of fixing time.

2. Place the strips in a tray of running water.

3. Remove the strips from the water and immerse for 2 minutes, with agitation, in a 0.2% solution of sodium sulfide (ventilation required).

4. Wash the strips for 20 minutes and allow to air dry.

5. Repeat steps 1 through 4 for the remaining six unexposed samples, **omitting the sodium sulfide treatment.** Note the color of the samples after treatment.

6. Choose and circle an area on each of the paper samples from which to take tricolor and visual density readings; record the readings.

7. Let the samples sit together, exposed to ordinary levels of room light (either fluorescent or incandescent) for one week. Take and record density readings again from the original areas.

Analysis

Write a report that describes and explains the variations in image tone and density among the 12 samples.

Questions

1. What is the purpose of the 0.2% sodium sulfide solution?

2. What is the characteristic yellow coloration that appears after immersion in the sodium sulfide solution?

3. Why do the fixed but unsulfided samples vary in tone?

4.5.3 Experiment 17: Test for Residual Silver Salts

Purpose

To demonstrate a test for residual silver salts.

Introduction

Residual silver compounds in black-and-white films and papers are a major cause of image staining and fading. An emulsion is considered completely fixed when it is possible to reduce the non-developed silver content to zero by subsequent washing.

It is currently thought that silver halides, when in contact with thiosulfate ions, form a silver thiosulfate complex consisting of one silver ion and one thiosulfate ion. This complex is relatively insoluble. However, in a solution of excess thiosulfate ions, a dithiosulfate complex is formed, consisting of one silver ion and two thiosulfate ions. This complex is water-soluble and relatively stable, as the silver ion is moved into solution. Every time a silver ion is removed, a halide ion (such as bromide or chloride or iodide) is released into solution. Exhausted fixers contain a large quantity of silver ions and a large quantity of halide ions. The affinity of halide ions for silver ions will eventually exceed the affinity of thiosulfate ions for silver ions. At this point, the fixing bath can no longer form more silver complexes from the silver halides. Washing alone will not completely remove these silver complexes which may result in fogging of the emulsion upon re-exposure to light. Only fresh fixing solution will remove these complex silver salts.

Exhausted fixer also will result in silver thiosulfate (the single silver ion to thiosulfate ion complex), which is much less soluble, to be retained by the photographic material, particularly paper fibres and the baryta layer. Exhausted alum hardener fixers, with a lower pH, cause silver thiosulfate complexes to be retained more readily by the baryta layer, paper fibre, and gelatin (Crabtree, 1943). These silver thiosulfate complexes are relatively unstable and will dissociate providing free silver ions which react readily with aerial agents, primarily hydrogen sulfide, to form yellow silver sulfide, which takes the form of stains in the low-density areas of prints and negatives (Haist, 1979).

The American National Standards Institute has published two procedures for determining if residual silver complexes are present in photographic materials. The first is ANSI Standard PH4.42-1983, *Determination of Silver in Photographic Films, Papers, Fixing Baths, Sludges, or Residues*. This test provides a quantitative measure; however, due to its somewhat complex nature, it will not be carried out in this experiment.

The second test is published in ANSI Standard PH4.32-1986, *Methods for Evaluating Processing with Respect to the Stability of the Resultant Image — Black-and-White Papers*. This test describes a method to determine the existence of residual silver complexes, rather than the actual amount.

Materials and Apparatus

- film and paper samples from Experiment 15
- 0.2% sodium sulfide solution, 100 mL
- transmission densitometer
- reflection densitometer

Procedure

1. Prepare the 0.2% sodium sulfide solution:

Distilled water	90 mL
Sodium sulfide	0.2 gram
Distilled water to make	100 mL

2. Six samples were produced for each of the three processing procedures, with and without toning, in Experiment 15. Take one from each group of six samples. Label these. At one end of each sample, pick two points in the non-image area, and circle these points. Take and record visual and tricolor density readings at these two points on each sample, using the reflection densitometer. Half of each sample will be treated and half left untreated. Two points are used to monitor the evenness of fixing.

3. Pour the 0.2% sodium sulfide solution into a beaker to a level of about five centimeters.

4. Place the six paper samples one at a time into the beaker, so that the two density reading points are immersed in the sodium sulfide solution. Leave the samples immersed for 3 minutes.

5. Remove the samples from the solution and wash in running water for 5 minutes. Squeegee the samples and air dry.

6. Repeat steps 2 through 5 for the two film samples. Dip the film samples in photo-flo for 30 seconds and hang to dry.

7. Take and record visual and tricolor density readings at the circled spots on each paper and film sample. Compare these readings to the before-treatment readings.
   A perceptible yellow stain will indicate the presence of residual silver complexes.

Analysis

Write a report that describes and explains the results of the sodium sulfide treatment.

Questions

1. How can the silver content of the fixer be monitored?

2. How does the silver thiosulfate complex affect the image? Under what conditions is this most evident?

4.5.4 Experiment 18: Test for Residual Thiosulfates in Photographic Materials

Purpose

To demonstrate two methods of determining the presence of residual thiosulfate in processed photographic materials.

Introduction

Residual thiosulfate is a contributing factor in the staining, yellowing, and fading of black-and-white photographic materials. To ensure that washing and hypo removal methods have been effective, several quantitative and qualitative methods have been devised to determine the presence and quantity of residual thiosulfates.

An early method to test the adequacy of washing times called for the combining of a solution of potassium permanganate with the water that drained from a washed negative or print (Jacobson, 1978). Crabtree, Eaton, and Muehler proved that this was an unsatisfactory method, as it measured the amount of dissolved thiosulfates and not the less soluble thiosulfates remaining in the image-forming layer, baryta layer, or paper base.

Two Tests for Residual Thiosulfates

Two methods of measuring residual thiosulfates have been used prior to the current ANSI/ASC Standard PH4.8-1985. *The Turbidity Method* (Crabtree, 1940) and the *Modified Turbidity Method* (Pope, 1963) compare solution density or opalescence of known concentrations of thiosulfate to that of a photographic sample immersed in a test solution (Crabtree, 1943). These two methods measure only the soluble compounds. An acidified silver nitrate test solution has been developed by Mattey and Henn, which reacts with any hypo in the film or print sample by turning a brownish yellow color. Using a Kodak Wratten Ultraviolet Filter, No. 18A in a transmission densitometer with a UV light source, or a reflection densitometer fitted with a Status A blue filter, and testing a series of films and prints, each having a known concentration of residual thiosulfates, a calibration chart can be produced to approximate the quantity of residual thiosulfates present in a sample being tested.

Methylene Blue Method

The Methylene Blue Method for measuring residual thiosulfate in films, plates, and papers (as outlined in ANSI/ASC Standard PH4.8-1985), is used primarily for film testing (Mattey, 1966). This method uses a calibration curve and a spectrophotometer to establish residual amounts of chemicals in materials, by measuring the absorbtion of light at 665 nm by the methylene blue dye produced in the test. Owerback has found that the methylene blue test has little validity when used for certain photographic paper types (Owerback, 1983). Owerback's colorimetric method, used to determine the amount of residual thiosulfate in processed paper, is well worth noting, but will not be examined in this experiment.

Silver Densitometric Method

The Silver Densitometric Method, as outlined in ANSI/ASC Standard PH4.8-1985, uses an acidified silver nitrate solution to react with residual thiosulfates, polythionates, and other residual chemicals that react with silver ions to form a stain. In an acidic environment, these compounds break down to form various sulfur compounds, which in turn react with the silver nitrate to form silver sulfide. Remaining silver is converted to a silver halide in a sodium chloride bath and then made soluble and washed out in a final fixing bath. Kodak has a similar test called the *HT-2 test.*

In this experiment, we will apply the Methylene Blue Method and the Silver Densitometric Method to paper and film samples produced in Experiment 15.

Materials and Apparatus

- ANSI/ASC Standard PH4.8-1985
- paper and film samples from Experiment 15 (must have been processed within two weeks)
- reflection and transmission densitometers
- spectrophotometer
- 6 11-mL shell vials with polyethylene caps
- 4 20-mL beakers

Silver Densitometric Method Reagents

silver nitrate
glacial acetic acid
sodium chloride
sodium sulfite
sodium thiosulfate

Methylene Blue Method Reagents

potassium iodide
potassium bromide
potassium dihydrogen phosphate
potassium borohydride
sodium hydroxide
sulfuric acid
ferric sulfate (monohydrate)
N,N-Dimethyl-p-phenylene diamine sulfate
silica gel, powdered (Florisil)

Part I — Methylene Blue Method: Procedure

1. Read ANSI/ASC Standard PH4.8-1985, *Residual Thiosulfate and Other Chemicals in Films, Plates and Papers — Determination and Measurement*. Keep a copy of this standard at hand during this experiment.

2. Prepare reagents for the Methylene Blue Method. All materials should be weighed on an analytical balance and all glassware thoroughly cleaned, rinsed with distilled water, and dried.

Eluent

Distilled water	600 mL
Potassium iodide	1.0 gram
Potassium bromide	20.0 grams
Potassium dihydrogen phosphate	1.0 gram
Distilled water to make	1 liter

Borohydride Reagent

0.2N sodium hydroxide solution	100 mL
Potassium borohydride (fresh)	3.0 grams

Ferric Sulfate Reagent

Distilled water	89 mL
Sulfuric acid	15 mL
Ferric sulfate (monohydrate)	3.0 grams

NND Reagent

Distilled water	89 mL
Sulfuric acid	15 mL
N,N-Dimethyl-p-phenylenediamine sulfate	1.0 gram
Powdered silica gel (Florisil)	5.0 grams

(Stir the mixture for one to two hours. Allow absorbent [Florisil] to settle, and filter.)

3. Before the test can be completed on samples, the solutions must be calibrated and a calibration curve drawn. Follow the procedure in ANSI/ASC Standard PH4.8-1985, Section 5.9. Draw a calibration curve for your reagents.

4. Paper samples from Experiment 15 consist of one toned and one untoned print from each of the three processing procedures, in addition to one toned and one untoned film sample. Cut these six print samples and two film samples into 1.6 cm × 6.25 cm pieces, taken from a low-density area. Fold the samples into **W** shapes, and place in individual 11-mL shell vials with polyethylene caps.

5. Complete the Methylene Blue Method, following the procedure outlined in Section 5.7 of ANSI/ASC Standard PH4.8-1985. If hypo levels are too high, no results will be obtained from the procedure, which is in the low range (0.1 to 0.9 $\mu g\ S_2O_3^{2-}/cm^2$). In that case, Procedure II (high range, 0.9 to 45 $\mu g\ S_2O_3^{2-}/cm^2$) will have to be used.

6. Report results in the form of a calibration chart and tabular data.

Part II — Silver Densitometric Test: Procedure

1. Prepare the reagents for the Silver Densitometric Method, using the following formulas:

Silver Nitrate-Acetic Acid Reagent

Distilled water	750 mL
Glacial acetic acid	30 mL
Silver nitrate	10 grams
Distilled water to make	1 liter

Sodium Chloride Reagent

Distilled water	750 mL
Sodium chloride	50 grams
Distilled water to make	1 liter

Sodium Thiosulfate-Sodium Sulfite Reagent

Distilled water, freshly boiled and cooled	750 mL
Sodium sulfite	19 grams
Sodium thiosulfate (pentahydrate)	50 grams
Distilled water, freshly boiled and cooled to make	1 liter

2. Use the same assortment of paper and film samples from Experiment 15, described in Part I. Cut film and paper samples from a minimum density area to specified sizes as outlined in Section 6.6.1.1 of ANSI/ASC

Standard PH4.8-1985. Film should be cut into strips 1.5 cm × 6 cm and folded in half. Paper samples should be cut into 1.5 cm × 3 cm strips. Label samples clearly.

3. Complete the test exactly as outlined in Section 6.6 of the standard. Do not deviate in any way from this procedure.
4. Results are indicated by densitometric readings. Film samples are read on a transmission densitometer equipped with a filter equivalent to a Kodak Wratten Ultraviolet Filter, No. 18A and which uses a photomultiplier tube as a detector. Where solid state detectors are used, see Appendix F of ANSI/ASC PH 4.8-1985. Paper samples are read using a reflection densitometer equipped with a filter equivalent to a Kodak Status A blue filter. Results are reported as density differences between stained and unstained areas.

Analysis

Write a report describing and drawing conclusions from the results of the Methylene Blue Method and Silver Densitometric Method as applied to the samples produced in Experiment 15.

Question

1. Can a direct correlation be made between the Methylene Blue Method and the Silver Densitometric Method?

4.5.5 Experiment 19: Toning for Permanence

Purpose

To demonstrate the effect of different toning solutions on various photographic paper emulsions.

Introduction

Photographers and those who use photographic materials in their work, as well as those who have custodial responsibility for photographic collections, are concerned with the propensity of the photographic image to fade and stain after periods of time in storage.

Sir John Herschel's discovery in the 1830s of the effects of "hyposulphite of soda" (sodium thiosulfate) solved the problem for later experimenters in the new photographic science of silver salts turning black when they were re-exposed to light. However, these sodium thiosulfate complexes soon presented their own problems. The residual chemicals from the fixing bath tended to degrade the silver image, leaving stained or faded areas on the prints. In the 1940s, J. I. Crabtree and G. T. Eaton showed that by using a saline solution, such as sea water or hypo clearing solutions, residual silver thiosulfate complexes are made soluble by two mechanisms: ion displacement and/or conversion into more soluble sulfates.

Despite the precautions used in contemporary photographic processes, modern silver gelatin prints and films and older historical photographic materials have a tendency to fade or show uneven yellowing. This yellowing is the manifestation of silver sulfide, formed by the action of a sulfuric oxidant, such as SO_2, on the image silver. As we shall see, sulfide compounds can be produced intentionally to create an even tone over the entire print surface and are extremely stable, much more stable than elementary silver. Therefore, deliberate sulfiding of a silver image enhances its stability. Color changes in sulfided images, which can range in color from yellow-brown to purple-brown, may also be desirable for aesthetic reasons.

Various other metallic salts, such as gold, selenium, iron, and uranium, can be used to enhance the stability of image silver. Each metallic salt has its own characteristic color and each may be used to produce a change in tone. This color tone is dependent upon the size and frequency of the filamentary image silver particles and the different wavelengths of light reflected by these silver particles. The smaller the grain size, the more the image tends toward a reddish tone (a longer wavelength of light). Conversely, the larger the filamentary silver particles, the shorter the wavelengths of reflected light, tending toward a bluish-black coloration. When the frequency of filamentary silver particles is great and the size large enough, no light is reflected from the visible spectrum. This produces a neutral-black image.

In the early 1850s, albumen (on both glass and paper supports) was introduced as a binding medium for the light-sensitive silver halides. Popular and scientific journals in the mid-1850s contain many references to the propensity of albumen photographs to fade and yellow. Various suggestions were implemented by photographers in attempts to prevent the fading. The most successful and most commonly used method was to immerse exposed albumen prints in an alkaline solution of gold chloride, followed by immersion in a strong thiosulfate solution. These solutions formed brownish to bluish toned images, depending on the character of the silver grains in the emulsion. This method of toning coated the silver grains with a thin layer of gold, thus providing a more stable metal that resists the effects of oxidizing gases in the atmosphere. This gold toning method is still in use today by a few commercial and art photographers.

Two commonly used contemporary methods for converting image silver in contemporary print materials to other, more stable, compounds are sepia toning and selenium toning.

Sepia toning is a method whereby the silver grains are bleached in a solution of potassium ferricyanide and potassium bromide. The bleached print is rinsed and then immersed in a solution of sodium sulfide, which converts the silver halides into silver sulfide. The brownish color of this toned image can be controlled by ferricyanide and bromide solution concentrations.

Selenium toning converts the metallic image silver to silver selenide. Depending on the initial processing of the photograph and the toning formula used, the image is toned from a deep brown to a violet-black. Selenium toners in very dilute concentrations (1:19) have been shown to provide much greater stability to photographic materials without altering significantly the image structure or tone. The selenium toning process is quite toxic with prolonged use. The powdered metal and solutions containing selenium should be handled with extreme care; protective gloves should always be worn while toning prints. (Proper ventilation is required!)

Materials and Apparatus

- exposure template from Experiment 1
- photographic paper, 8" x 10", 6 sheets each:
    - Ilford Ilfobrom Galerie 2.1K
    - Ilford Multigrade II RC
    - Kodak Azo grade 2
    - Kodak Polycontrast Rapid III RC
- Classical Processing Procedure chemicals
- Ilford Galerie processing chemicals
- toners: (chemicals listed in text below)
    - Kodak Rapid Selenium Toner
    - Kodak Sulfide Sepia Toner T-7a
    - Light Impressions Gold Protective Treatment
- reflection densitometer
- contact printing frame
- trays, 8" x 10"
- archival print washer
- Kodak Liquid Hardener
- prepared Kodak Curve Plotting Graph Paper
- NuArc point light source

Procedure

1. Using the point light source, contact print the exposure template to each paper sample. Expose and process the paper samples using the processing procedures outlined in Section 4.5.1. Label all samples clearly. (Ilford Ilfobrom Galerie paper should be processed according to the *Ilford Ilfobrom Galerie Processing Procedure*. The remaining three types of paper can be processed according to the *Classical Processing Procedure.*) Exposure and development of the different paper types should be such that the mid-tone densities match each other as closely as possible.

2. Measure and record visual and tricolor density readings for all of the samples.

3. Prepare toning solutions when ready for use as directed below:

    a. *Kodak Rapid Selenium Toner*
    Dilution A: 1:3

Distilled water	375 mL
Kodak Rapid Selenium Toner	125 mL

Kodak Rapid Selenium Toner
Dilution B: 1:19

Distilled water	475 mL
Kodak Rapid Selenium Toner	25 mL

b. *Light Impressions Gold Protective Treatment*

Distilled water	800 mL
Stir in concentrate A	10 mL
Pour in slowly with constant stirring, concentrate B	25 mL
When solution clears, add distilled water to make	1 liter

(Working capacity is 8 8" × 10" prints per liter)
Use immediately after mixing.

c. *Kodak Sulfide Sepia Toner T-7a*

Stock Bleaching Solution A:

Distilled water	2.0 liters
Kodak potassium ferricyanide (anhydrous)	75.0 grams
Kodak potassium bromide (anhydrous)	75.0 grams
Potassium oxalate	195.0 grams
Kodak 28% acetic acid	40.0 mL

Stock Toning Solution B:

Sodium sulfide (anhydrous)	45.0 grams
Distilled water	500 mL

4. Tone each print sample, according to the following procedures:

a. *Kodak Rapid Selenium Toner*

i. Place processed print samples into the print washer (water at about 22°C) for three minutes to swell the gelatin.

ii. Pour Dilution A into an 8" × 10" processing tray, on the rocker table.

iii. Treat samples one at a time for three minutes each in this solution.

iv. Wash prints for 25 minutes.

v. Wipe with a squeegee and air dry.

vi. Repeat procedures 1 through 5, using Dilution B.

b. *Light Impressions Gold Protective Treatment*

i. Place processed print samples into the print washer for three minutes to swell the gelatin.

ii. Pour freshly mixed solution into an 8" × 10" tray, on the rocker table.

iii. Immerse the print samples one at a time, emulsion up in the toning bath. Leave them for 10 to 12 minutes or until a barely perceptible shift occurs in image color (toward bluish-black). Some papers will take longer than others; some will show no color shift.

iv. Wash for 25 minutes in running water.

v. Wipe with a squeegee and air dry.

c. *Kodak Sulfide Sepia Toner T-7a*

i. Prepare the bleaching bath as follows:

Stock solution A	500 mL
Distilled water	500 mL

ii. Prepare the toner as follows:

Stock solution B	125 mL
Distilled water to make	1.0 liter

iii. Prepare a 1:13 solution of Kodak Liquid Hardener and distilled water.

iv. Immerse one processed print from each paper type in the bleach solution. Allow each print to remain in the solution until the image disappears, or turns yellow and lightens in the shadow areas.

v. Wash the samples for five minutes in running water.

vi. Immerse each of the samples in the sodium sulfide solution for one minute, or until the image reappears completely.

vii. Wash each sample for one minute in running water.

viii. Immerse each sample in the hardening bath for five minutes.

ix. Wash each sample for 30 minutes in the archival print washer, and allow to air dry.

5. Measure and record all visual and tricolor densities for each sample.

6. Using a single sheet of prepared Kodak Curve Plotting Graph Paper, draw characteristic curves that show how a single paper type reacts to each toner. Use the visual densities.

7. Using a single sheet of prepared Kodak Curve Plotting Graph Paper, draw characteristic curves that show how a single toner affects the various papers.

Analysis

Write a report that describes the effects of the toning experiments above. Explain why different papers respond differently to the various toners.

Questions

1. What is the mechanism for each of the types of toners?

2. How, and to what degree, is the hue of the processed image affected by toning? What causes this effect?

3. Why is it essential that the prints be thoroughly washed and the thiosulfate complexes removed before toning takes place?

4.6 References

Crabtree, J.I., et al. 1940. The Elimination of Hypo from Photographic Images. *Photographic Society of America Journal* **6**: 6-13,24.

Crabtree, J.I., et al. 1943. The Removal of Hypo and Silver Salts from Photographic Material as Affected by the Composition of the Processing Solutions. *Journal of the Society of Motion Picture Engineers* **41**: 9-68.

Drago, F.J., and W. E. Lee. 1984. Stability and Restoration of Images on Kodak Professional B/W Duplicating Film/4168. *Journal of Imaging Technology* **10**(3): 113-118.

Eastman Kodak. 1984. *Black-and-White Film and Paper Processing and Process Monitoring,* 14. Kodak Publication, no. Z-128. Rochester, N.Y.: Eastman Kodak Co.

Haist, Grant. 1979. *Modern Photographic Processing.* New York: John Wiley & Sons.

Jacobson, Ralph C. 1978. *The Manual of Photography.* London: Focal Press Ltd.

James, T. H., ed. 1977. *The Theory of the Photographic Process.* 4th ed. New York: Macmillan.

Langford, Michael. 1986. *Basic Photography.* 5th ed. London: Focal Press.

Lee, W.E., et al. 1984. New Procedures for Processing and Storage of Kodak Spectroscopic Plates, Type 111a-J. *Journal of Imaging Technology* **10**(1): 22-26.

Mattey, D.A., and R. W. Henn. 1966. Determination of Thiosulfate and Thionates in Film with Silver Nitrate. *Photographic Science and Engineering* **10**(4): 202-208.

Owerbach, D.A. 1983. Colorimetric Determination of Residual Thiosulphate (Hypo) in Processed Paper. *Journal of Applied Photographic Engineering* **9**(2): 66-70.

Pope, C.I. 1963. Stability of Residual Thiosulphate in Processed Microfilm. *Journal of Research of the National Bureau of Standards* **67C**(1): 15-24.

Sturge, John M., ed. 1977. *Neblette's Handbook of Photography and Reprography Materials, Processes and Systems.* 7th ed. New York: Van Nostrand Reinhold.

4.7 Supplemental Readings

Anon. 1860. Toning. *American Journal of Photography and the Allied Arts and Sciences* (New York) 2: 270-271.

ANSI. 1983. *Determination of Silver in Photographic Films, Papers, Fixing Baths, Sludges, or Residues.* ANSI PH4.42-1983. New York: American National Standards Institute.

ANSI. 1985. *Residual Thiosulfate and Other Chemicals in Films, Plates and Papers — Determination and Measurement.* ANSI PH4.8-1985. New York: American National Standards Institute.

ANSI. 1986. *Methods for Manual Processing of Black-and-White Photographic Films, Plates, and Papers.* ANSI PH4.29-1986. New York: American National Standards Institute.

ANSI. 1986. *Methods for Evaluating Processing with Respect to the Stability of the Resultant Image — Black-and-White Papers.* ANSI PH4.32-1986. New York: American National Standards Institute.

Asloglou, E. 1938. Selenium Toning Methods for Prints. *British Journal of Photography*, Sept.-Oct., 599-600, 612-613, 629-630, 643-644, 662-663.

Bachrach, D. 1888. Chloride of Gold: How to Make It — Its Uses in Photography. *Photographic Mosaics*, 43-46.

Baeckstroem, H., and A. Bostroem. 1936. The Influence of the Bleaching Bath on the Colour Obtained in the Indirect Sulphide-Toning Process. *Photographic Journal* (London), Dec., 607-612.

Carroll, J.S. 1975. *Photographic Facts and Formulas.* Rev. of original by E.J. Wall and F.I. Jordan. Englewood Cliffs, N.J.: Prentice-Hall.

Carroll, J.S. 1979. *Photographic Lab Handbook.* 5th ed. Garden City, N.Y.: Amphoto, 231.

Coote, J. H. 1970. *Photofinishing Techniques and Equipment*. London: Focal Press.

Crabtree, J.I. 1930. D. and P. Practice. *British Journal of Photography*, Aug.-Sept., 487-489, 506-508, 521-524, 535-537, 552-554, 572-574.

Eastman Kodak. 1973. *Processing Chemicals and Formulas for Black-and-White Photography.* Kodak Publication, no. J-1. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1985. *Practical Densitometry.* Kodak Publication, no. E-59. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1985. *Conservation of Photographs.* Kodak Publication, no. F-40. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1987. *Kodak Professional Black-and-White Films.* Kodak Publication, no. F-5. Rochester, N.Y.: Eastman Kodak Co.

James, T.H., and G.C. Higgins. 1968. *The Fundamentals of Photographic Theory.* 2nd ed. Dobbs Ferry, N.Y.: Morgan & Morgan.

Jenkins, Reese V. 1975. *Images and Enterprise: Technology and the American Photographic Industry.* Baltimore: The Johns Hopkins University Press.

Lee, W.E., et al. 1984. Toner Treatments for Photographic Images to Enhance Image Stability. *Journal of Imaging Technology* **10**(3): 119-126.

Mason, L.F.A., et al. 1981. Processing Black-and-White Prints on Paper Base for Permanence. *Journal of Applied Photographic Engineering* **7**(2): 64-66.

Nitze, H. 1932. Paper, Developer and Bleach in Sepia Toning. *British Journal of Photography,* Aug., 486-487.

Reilly, J.M. 1978. The Manufacture and Use of Albumen Paper. *Journal of Photographic Science* **26**(4): 156-161.

Rothschild, N. 1973. How to Use the "Classic" Toners. *Popular Photography,* Oct., 106-109, 203, 212.

Sedlaczek, E. 1928, 1929. Selenium Toning Processes [Die Tonung mit Selenverbindungen]. *British Journal of Photography,* Dec. 28, 784-785; Jan. 4, 4-6; Jan. 18, 29-31; and Jan. 25, 44-46.

Todd, H.N., and R.D. Zakia. 1974. *Photographic Sensitometry: The Study of Tone Reproduction.* 2nd ed. Dobbs Ferry, N.Y.: Morgan & Morgan.

Weyde, E. 1962. Grosse und Form des entwickelten Silberkornes und seine Beziehungen zu bildwichtigen Eigenschaften [Size and Shape of the Developed Silver Grain and Its Relationship to Image Properties]. *Photographische Korrespondenz* **98**(1): 7-12.

Skidegate Indian village (Haida Tribe). Skidegate Inlet, Queen Charlotte Islands, British Columbia. July 26, 1878. George M. Dawson. Contemporary print from wet collodion glass plate negative (detail). National Archives of Canada/PA-038152.

5 Historical Photographic Processes

5.1 Identification of Photographic Processes

5.1.1 Introduction

Photography by definition is "any system for converting to a more or less permanent and visible form images produced on supports by the action of ultra-violet, visible or infra-red radiation" (Spencer, 1973). Photographic processes developed over the past 150 years or more have produced countless images that are full of information and history. When we look at a photograph we are drawn to its image, rarely considering what it is made of or how it was produced. During the history of photography, a tremendous variety of materials and processes has been used to produce photographs. Early photographers, especially during the first 40 years of photography, had to manufacture their own photographic materials. Commercially available products were few and dedicated photographers found they could modify existing processes to better meet their needs.

In order to enhance the student's ability to correctly identify various photographic processes and materials, this chapter has been structured to provide opportunities for the direct examination of historical materials. There is no substitute for seeing and handling original historical materials; however, this chapter also includes the description of photographs made of many different materials. Although there exist a great many photographic processes, many of the specialized or modified processes may be categorized into general groups that are described in the following pages. During the past 15 to 20 years, photographic artists have rediscovered many of the earlier photographic processes. Not only have they rediscovered and revised old processes, they are also employing many of the methods used to change the visual impact of a photograph by painting or hand-coloring it. Color photographs have been included in this chapter as a separate group. Included are exercises in which the student actually produces photographs made by several 19th- and 20th-century processes. Suggested readings support the work, which discusses some of the properties of these processes.

5.1.2 Identification of Historical Processes

In the following description of the main photographic processes and the photographs they produced, an attempt is made to classify the various types according to their structure and physical properties which, in turn, determine their preservation requirements. The use of format as the distinguishing feature (e.g., *carte-de-visite*), or physical appearance (e.g., case photographs, such as a daguerreotype or an ambrotype) is less useful, as these features do not necessarily point to any one type of photographic structure. A *carte-de-visite* could be either an albumen print or a silver gelatin print, both of which would differ considerably in their properties. Likewise, a daguerreotype, as will be shown later, was made by a process different from the wet collodion process by which an ambrotype was made. Black-and-white photographs can be divided into two main categories: camera originals which are records exposed in a camera that are usually negatives; and reflection print materials.

Camera Originals

Daguerreotypes

In 1839, L.J.M. Daguerre, a French painter, announced the invention of the daguerreotype. It consisted of an image made of microscopically small particles of silver amalgam, an alloy of mercury and silver, on a silver-plated copper plate. The daguerreotype process was very popular in

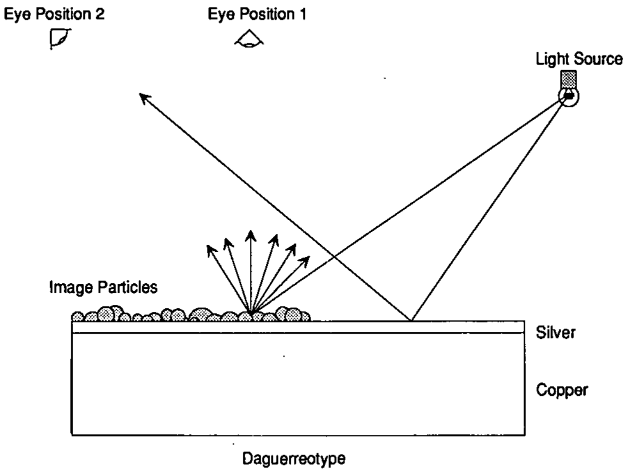


Fig. 5.1: The angles of illumination and viewing of a daguerreotype plate.

If a beam of light from a point light source strikes a polished silver surface at a certain angle, an observer in position 1 sees the color black, since none of the reflected light reaches the eye. The light is reflected at an angle equal to the angle of incidence, and therefore an observer in position 2 sees the polished silver surface. In a second case, when the silver surface also contains more or less fine silver amalgam particles, light is then scattered in all directions, thus reaching the eye of an observer in position 1. These light-scattering phenomena are responsible for the appearance of a daguerreotype as both a positive and a negative image, depending on the angles of illumination and observation (Pobboravsky, 1971).

North America until the mid-1860s. Images made by this process have a jewel-like appearance and are of a delicate nature: they are sensitive to chemicals in their environment and are liable to be scratched by the touch of a finger. Consequently, they are usually kept under a glass cover in a small case made of leather, wood, or plastic and are often referred to as "case photographs." The "union" case made its appearance in 1854. Union cases were made of a plastic material consisting of shellac (black or brown coloring), excelsior, groundwood, or sawdust pressed in dies or moulds of a detailed design. Each of these cases usually requires individual and careful treatment, according to its condition. The word "union" was taken from the original patent (Welling, 1976).

Daguerreotypes, strictly speaking, are negatives but appear to the viewer alternately as a positive or a negative picture, depending on the angle of illumination and observation. In contrast to reflection prints, where the image is visible because of the absorption and reflection of incident light, the daguerreotype image is visible because of a light-scattering phenomena (Pobboravsky, 1971).

When found in cases, daguerreotypes are combined with an overmat covered by glass, an assembly held together by a gilt frame.

Calotypes and Historical Paper Negatives

Daguerreotypes were unique camera originals, of which copies could not be made. In the late 1830s, the English inventor W.H. Fox Talbot exposed paper sheets coated with a "sensitizing" solution in order to obtain paper negatives. The beginning of the negative-positive process as we know it today was announced by Talbot in 1839 (Talbot, 1839). A paper negative, in which the bright areas of the original scene appeared dark and the shadow parts appeared light, could be printed, or exposed to light in contact with a second sensitized sheet of paper, to obtain a laterally and tonally correct positive image of the original scene. These positives were called "salted paper prints" or "salt prints."

Such original paper negatives, in use for about the first 20 years of photography, are rare and of great intrinsic value. Each required individual treatment as would a watercolor or a lithograph. During the 1850s, the paper negative was often waxed in order to make the support more transparent and so facilitate printing.

Wet Collodion Negatives on Glass and Direct Positives Made by the Wet Collodion Process

Introduced in England by F.S. Archer in 1851 (Archer, 1851), the majority of photographic negatives made during the second part of the last century were exposed on wet collodion glass plates. Collodion, a solution of cellulose nitrate compound in a mixture of alcohol and ether, was mixed with a halide salt, poured onto a glass plate with a clean surface, and finally sensitized by bathing it in a solution of silver nitrate. In this way, a light-sensitive silver halide was formed. The glass plate so prepared had to be exposed in the camera while it was still wet, hence the name of the process. If the collodion were allowed to dry, the plate would lose its sensitivity.

As the exposed negative was physically developed, the resultant silver image was composed of extremely fine silver grains. Wet collodion glass plate negatives, therefore, have a high resolving power and are capable of rendering fine detail. Because of this property, wet collodion negatives were used until World War II in the preparation of photolithographic printing plates. They were usually varnished — a fact that has contributed to the preservation of their image silver. Yellowing of these negatives may well be due to a deterioration of the varnish and not of the collodion or the image silver.

This process was also used to make direct collodion positives, which are now known as ambrotypes and tintypes. After exposure in the camera, the glass plate negative was backed with black paper or a black lacquer, which made the image appear to be a positive. The result was an ambrotype. Sensitized collodion layers were poured on black lacquered iron plates in order to obtain the same effect. The resulting image was called a tintype. Ambrotypes and tintypes were often kept in cases similar to those described for daguerreotypes (also called "case photographs").

The materials up to this point are distinguished from the subsequent silver gelatin materials by two criteria: they were individually handmade, and they were sensitized immediately before use by the photographer. The light sensitive salt — a silver halide — was formed in a direct chemical reaction on the surface of the respective support just prior to exposure.

Silver Gelatin Dry Plates

Over the past 100 years, the predominant photographic systems have been made up of light-sensitive silver halides suspended in a highly purified gelatin binder. The use of gelatin as a binder made possible the coating of the support with a sensitive silver halide in the gelatin layer well before exposure. This allowed the eventual development of a manufacturing industry in which the empirically acquired skills of manufacture, developed since the 1880s, gave way to more scientifically understood and controlled procedures. These allowed the emulsion-maker to make many different kinds of black-and-white photographic films and papers. Especially important was the manufacture of papers with varying degrees of contrast.

The first of these silver gelatin images were dry plates which became rather common after 1880. One major drawback was the weight of the glass and its brittleness, a property they shared with wet collodion glass plate negatives. However, they were more sensitive to light and they kept their sensitivity for several months after manufacture. The majority of still camera negatives taken during the last two decades of the 19th century and about the first 20 years of this century are gelatin dry plates. However, not all images on these plates are necessarily negatives, as they could be processed by reversal development to give positive transparencies, sometimes called lantern slides.

Silver Gelatin Negatives on Plastic Films

During the latter part of the 19th century, many attempts were made to coat plastic materials with light-sensitive emulsions in order to overcome the disadvantages of glass plate negatives. Around 1890, the first photographic films on a plastic base made of cellulose nitrate appeared on the market. The development of this film base laid the foundation for the tremendous growth of the motion picture industry. Several years after the commercial introduction of cellulose nitrate film base, it became apparent that this material tended to slowly disintegrate with age and was also highly inflammable. New materials were developed, the three most important ones being cellulose diacetate, introduced in the late 1920s, and cellulose triacetate (late 1940s) and polyester film base, developed during the 1950s. These materials are often referred to as safety film. They form the bulk of still photographic negatives in most historical collections, along with black-and-white prints made on developing-out papers.

Reflection Print Materials

Of the many processes that were used to make positive reflection prints, the predominant ones are based on silver and gelatin. They are grouped according to the nature of the image-forming substance first, then according to the binding agent, and lastly according to the support. The image-forming material — silver, carbon, metal salts, etc. — largely determines the important characteristics, including the stability of a photograph. The support is generally the least influential factor as it is the most stable of the three components and rarely causes problems. Exceptions are the earliest photographs on paper, and resin-coated papers after they were first introduced.

Printing-Out Photographic Paper Prints

Printing-out papers that contain silver halides are exposed by contact under a negative until a positive picture appears. This process may take from a few minutes to 45 minutes or more, depending on the type of paper and the light source used. There is no subsequent development. The picture is then toned and fixed. The silver grains obtained in the printing-out process are considerably smaller and of a different shape than those present in developed-out papers. The most common types of these photographic prints are subdivided into the following groups.

Salt Prints, or Salted Paper Prints

Salted paper prints are positive materials and have been mentioned earlier as rare and historically important documents. Since there is no binding agent in these pictures, they often have a somewhat flat appearance, lacking brilliance and depth. However, the paper used was sometimes sized with gelatin first, which caused a change in the properties of the resulting pictures.

Starch was also used as a sizing agent, but photographs of this kind are rare, and little information has been published about them.

Albumen Prints

Albumen prints are probably the most common and, therefore, the most important photographic print material of the 19th century. Consequently, there is an abundance of literature on their manufacture, use, and properties. The exposure range and the almost complete lack of graininess of albumen papers perfectly match the high-contrast and fine-grain of the wet collodion negatives, from which they were generally printed. These are the first machine-made papers produced specifically for photographic purposes. Albumen prints are usually an important part of most historical collections.

Collodio-Chloride Prints

An important print material, in which the albumen was replaced by a collodion layer, seems to have been used more in Europe than in North America. Although albumen papers, coated only with egg white containing a halide salt, were usually sensitized before use by the photographer, collodio-chloride papers were completely machine manufactured. In contrast to the former, collodio-chloride prints have a baryta layer between the paper support and the collodion layer. A baryta layer, introduced well over 100 years ago, consists of finely ground, white barium sulfate in gelatin.

Silver Gelatin Printing-Out Papers

The introduction of printing-out papers made of gelatin or collodion was considered the beginning of the end for the albumen paper. The decline of the albumen process began in the 1890s as more photographers favored the image stability of the new printing-out papers. Albumen papers were still manufactured until the 1920s. The printing-out materials were machine-coated and could be purchased in a wide assortment of surfaces, image colors, and contrasts. These papers were much more stable than the albumen papers, which have a tendency to yellow in the highlight areas.

Developing-Out Papers

Developing-out paper was, and still is, the most common photographic printing medium since the end of the last century. Developing-out papers are exposed in a darkroom under a negative for a few seconds and then developed. Their speed is one of the major advantages over printing-out papers.

According to the halide used and, therefore, to the size and shape of the resultant silver grain, developing-out papers have traditionally been divided into chloride, chlorobromide, and bromide papers.

Bromide Papers

Bromide papers were the first developing-out papers to appear on the market in the 1880s. Their stability was once considered to be so high, in comparison with printed-out photographs, that one manufacturer sold his product under the name of "Permanent Bromide." Bromide papers were of medium speed and had neutral image tones. As the manufacture of these materials became more complex, the simple term "bromide" indicated that the predominant light-sensitive compound in the material was silver bromide.

Chloride Papers

These print materials contained silver chloride as the prevalent light-sensitive compound. Being of relatively low speed, they were mainly used for contact printing. The finished print has a warm-black image tone, a higher maximum density than the other developing-out papers and fine grain. As early versions could be used in a moderately lit workroom, they were also referred to as "gaslight papers."

Chlorobromide Papers

Chlorobromide papers contained a larger quantity of chloride than bromide and were regarded as projection-speed enlarging papers and were used in many commercial applications. A distinction between such prints and the two preceding prints by visual inspection alone is almost impossible. The general earlier remarks about developing-out printing papers apply here also.

Resin-Coated Papers

These photographic papers (in French called *papiers PE*, for polyethylene), which were developed during the past 25 years or so, are grouped separately here because they have been shown to exhibit stability characteristics that are different from conventional materials. They are, of course, developing-out papers, and their sensitometric properties are similar to comparable materials on a non-RC base. Yet the presence of a very thin polyethylene layer on either side of the paper sheet has made them suspect of being less stable than conventional black-and-white papers.

It was discovered that when early resin-coated papers were displayed for prolonged periods of time, chemical reactions in the RC layer were triggered. This could result in crazing (mosaic cracking) of the image layer, which made the structure less pliable. Many methods of reducing this were evaluated, and it was found that certain stabilizers could be incorporated in the base that would prevent this form of deterioration.

Miscellaneous Historical Print Materials

Non-Silver Printing Materials

During the second half of the 19th century, when the potential instability of silver prints became apparent, many attempts were made to replace the silver with a more stable material, such as printer's ink or suspensions of carbon particles (lampblack) in gelatin. Many processes were tried, but only a few have gained high rank and recognition for their perfect rendering of tones and their permanence. These are the Woodburytypes, carbon prints, collotypes, and photogravures, as well as modifications of these processes. Other processes that must be mentioned here are handmade, non-silver and pigment printing processes such as platinum prints and bromoil prints respectively.

Color Photographic Materials

Color photography as we know it today came into being in 1935 with the commercial introduction of Eastman Kodak Kodachrome Film, a subtractive color process. The earliest commercial color photographic process before that date was the Autochrome Transparency Plate made by Lumière in 1904. It used an additive screen plate process, which is based on the additive system of color formation. The screen plate process incorporated a method that covered the support with tiny colored filters and then the layer of filters was coated with a color-sensitive emulsion. A color photograph was obtained by exposing the material through its back in a camera (filter towards the lens). Other manufacturers followed with their own products, the best-known of which are the Finlay Colour Plate, the Dufay Colour Plate, the Agfa Colour Screen Plate, and the Duplex Colour Plate. All of these products were rapidly superseded in the marketplace by the appearance of the subtractive systems of color formation. The latter may be grouped into these major categories:

1. *Chromogenic color processes* are color photographic systems in which the color dyes are generated by a chemical reaction between color couplers and a by-product of development.
   - *Substantive systems* are systems in which the color couplers are incorporated in the emulsion during manufacture.
   - *Nonsubstantive* (Kodachrome type) is a process by which, instead of putting couplers into the emulsion, they are introduced during the processing sequence.
2. The *dye imbibition process* is one in which a hardened positive gelatin relief matrix is used to transfer absorbed dye to a gelatin coating on paper, by contact (Spencer, 1973).
3. The *silver dye bleach process* is "based on the oxidative or reductive decomposition of azo dyes by a silver-catalyzed bleach reaction" (Krause, 1989).
4. *One-step photography* (diffusion transfer process) is the transfer of soluble images from one layer to another (Walworth et al., 1989).

Identifying Print Processes

There is no easy and quick way to identify photographic materials. The exceptions are, of course, materials that have the manufacturer's logo and the brand name embossed or printed on them. There are several simple laboratory tests, yet they are not always conclusive. Beyond that, complex analytical techniques have to be applied that require expensive instrumentation.

The best help in this respect is to gain experience in looking at photographs and working with them. Through experience it is possible to develop a degree of certainty about which type of film or photograph one is dealing with. Knowledge of the exact date of a photograph can eliminate some materials and narrow the alternatives down to a few. The following table shows the major photographic processes throughout the history of photography.

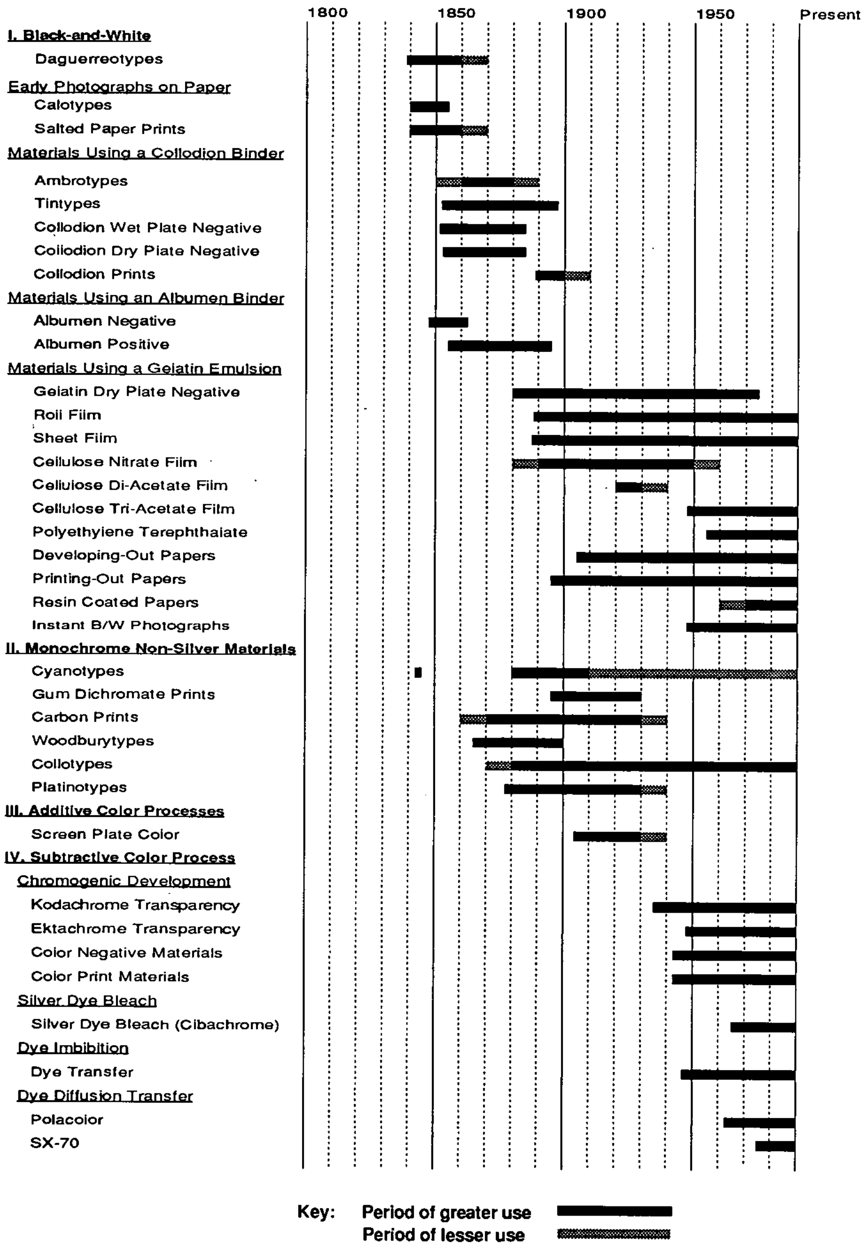


Fig. 5.2: Chronology of historical processes.

Several pamphlets have been published, which are designed to guide the keeper of still photographic pictures through the tremendous variety of photographic images and towards a recognition of the principal processes. Of these, the paper by Gill (1978) and the book by Reilly (1986) are recommended. The identification of photographs can be divided into the following techniques:

1. Visual examination:
   - a. size of picture
   - b. type of margin
   - c. backprint identifier
   - d. color (b/w or color)
   - e. inscriptions
   - f. date
   - g. mounting method
   - h. image tone
   - i. contrast
   - j. surface texture
   - k. support material
   - l. grain
   - m. presentation method
   - n. overpainting
   - o. discoloration
   - p. thickness of paper
   - q. gloss

2. Microscopic examination: examination under magnification of 10 times or higher.

3. Identification by cross-section: a destructive testing procedure. Viewing the sample's various components under high magnification using a light microscope or transmission electron microscope.

4. Chemical testing methods: can be destructive. Use of various solvents and chemicals for testing components of the photograph.

5. Destructive analytical testing methods: use of expensive analytical devices that quantify aspects of the photographic material (i.e., EDX, etc.).

6. Non-destructive testing methods: chemical analysis that quantifies various components of photographic materials (i.e., REXES).

Although some of these methods may not be available to a conservator, it is possible to distinguish photographic materials using the first four methods. These identification methods and chemical composition of the materials can clearly show specific features of the photographic structure.

When destructive tests are not desirable, or expensive equipment and staff are not available, the ability to look critically at a photographic image is the most effective tool in the identification of photographs. The student may gain experience in assessing the preservation conditions of materials by looking for cracks, breaks, fading, or yellowing. There are many types of surfaces as well as image tones occurring in various photographic images. The better one's familiarity with them, the better one's ability to examine and evaluate the condition of the record under investigation. Lighting also plays an important role when viewing photographs, since the amount and color of the light source can greatly affect the way we see fine details and textures of the photographic sample. When examining photographs for identification purposes, the viewing conditions should be such that the color of the light source be as close to daylight as possible with an acceptable level of illuminance (approximately 130 footcandles). Although daylight would be the most desirable, this is not always possible; other light sources are acceptable as long as they have an output that is bright enough to allow fine details to be clearly seen.

The light microscope and stereomicroscope extend the ability of the human eye to see and identify details at various magnifications. The stereomicroscope allows a wider field of vision compared to a light microscope, and depending on the type of stand, this design of microscope permits the examination of photographic materials without any restraints. The use of either device is probably the single most important instrument in the conservation laboratory. The usefulness in examining cross-sections of films, and papers, and in examining specific features too small for the eye to see, allows for a more accurate identification of materials.

Students and photographic conservators should approach the task of identifying photographs in a systematic way. Proficiency and experience do not preclude adhering to the basic steps involved in the recognition of photographic processes.

The best way to identify photographs is to evaluate them by three important attributes: color, texture, and fading.

1. *Color:* For color materials it may be the saturation of a color; for black-and-white materials color is indicative. Black-and-white can be a multitude of shades of grey; black can be a warm-black, a bluish-black (cold), reddish-black, or a chocolate-brown.

2. *Texture:* The surface of prints can have many patterns and surface sheens. "Mat" is texture without sheen (flat in appearance); glossy has high reflection.

3. *Fading:* Some photographs are unstable by their nature. Fading may occur in untoned silver-based photographs; it is caused largely by chemically aggressive substances reacting with the image silver. Examples of such substances are residual processing chemicals or materials that are part of atmospheric pollution. The effect of fading on the photograph may be a loss of contrast and a shift in color towards tones of yellow or brown. The complete absence of fading or discoloration, particularly noticeable in the highlights, indicates non-silver images (e.g., carbon prints) or silver photographs toned with salts of gold or platinum.

Keeping these main points of reference in mind, let's begin by looking at the figure below.

Fig. 5.3: A typical Canadian scene that was produced using a historical printing process, which will be identified in the following pages.

With anything that is tangible, we generally prefer to touch and view the object from all angles (**use reference samples only**). So, in a viewing area that has been set up as described in Section 5.1.2, view the object from all angles. Feel the surface of the support without cotton gloves (e.g., paper and polyethylene feel different), and look at the thickness of the support. Examine the image, looking for clues as to its date (inscriptions, costumes, etc.). Look at the surface texture, color of the blacks, and various forms of deterioration.

The first viewing of the photograph should be a very quick overall examination with the purpose of getting a "feel" for the object. During this first step, it is important to train your eyes to "see" all aspects of the photographic material.

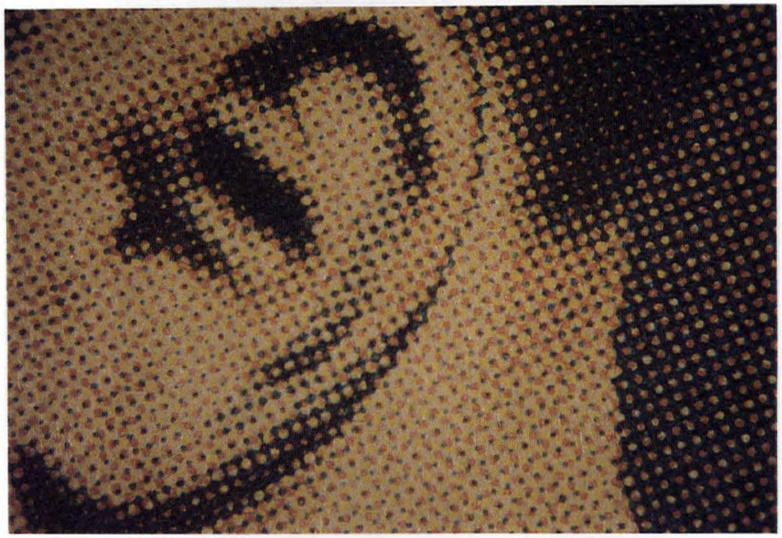


Fig. 5.4: This represents a half-tone reproduction showing the dot pattern.

Sometimes there is the tendency to omit specific points of reference when identifying processes. For example, we could look at a print that is blue in color. We recall that a cyanotype image is a rich blue color, with a mat surface texture, and visible paper fibres. One could conclude from this small amount of information that the image is a cyanotype. Upon further examination, based on visual investigations, microscopic analysis, and the observation of surface characteristics, the print may later be identified as being a gum dichromate print that has incorporated a blue watercolor pigment. Following some basic guidelines can be beneficial.

Fig. 5.5: Contemporary sample of a historical printing process.

The first decision that must be made is whether the object that is to be identified is actually a photograph (Gill, 1978). Generally, a hand magnifier will show whether the image is continuous tone or is broken into tiny lines, dots, or grain structure, similar to magazine and newpaper pictures (see Figure 5.4).

The next decision is whether the photograph is negative or positive. Viewing the material (whether negative or positive) by reflected light can give relevant physical characteristics that otherwise may have not been noticed. A negative appears, whether on glass, paper, or plastic, as if the tones are the reverse of the brightness range of the original. In this case, Figure 5.5 is a positive. So, at this point we know that the image in Figure 5.5 is:

1. continuous tone,
2. positive image.

The third level of decision-making involves identifying the layer structure of the photograph. "There are three possible layer structures: one-layer, two-layers, or three-layers" (Reilly, 1986). One-layer materials have the image-forming substance on and in the paper support. A two-layer structure is characterized by a binder layer (that holds the image particles) on the support. Three-layer materials consist of a binder, a baryta, and a support layer. This can be very difficult for the student because one-layer materials can look virtually identical to two-layer materials. The image from Figure 5.5 has a two-layer structure, which can be recognized by the varying thickness of the image layer and the appearance of the paper fibres in the highlight areas under magnification (10 times).

The final decision is based on recognizing individual characteristics and details specific to the object. Some of these features include: various forms of deterioration, mounting methods, color, texture, thickness of the support, gloss, contrast of the image, and edge marks. The image can be recognized by these points:

1. continuous tone,
2. positive image,
3. two-layer structure (paper fibres are visible in the highlight areas but not in the dark regions),
4. no visible forms of deterioration,
5. pale blue color,
6. contrast is low,
7. image sharpness is fair,
8. ability to retain fine shadow detail is poor,
9. image relief (between highlight region and dark areas).

The information that has accumulated indicates that Figure 5.3 could be a carbon print or a Woodburytype. However, the color from Figure 5.3 is blue. We then ask ourselves what process is characterized by continuous tone, positive image, two layers, blue in color, having a relief, lacking contrast, and having a slight surface gloss. The answer is a gum dichromate print.

Once a choice is made, the steps involved in reaching this decision should be reviewed and the characteristics of the photographic material under investigation should be double-checked against a labelled and known sample.

The following identification clues summarize some of the physical aspects of historical objects that most students will, at one time or other, be asked to identify. The illustrations are presented so as to allow the student to visually relate the photographs to the appropriate information page that contains information on the period of use, structure (photomicrograph, cross-section or illustration), visual surface qualities, and other special notes. This type of "Process Clues Page," and other identification guides, will assist the examiner in better identifying photographic materials.

Fig. 5.6: Poor detail in the shadows is an indication of a type of photographic process.

Fig. 5.7: Example of an image showing a "relief effect," where the shadow areas are glossier and are more elevated than the highlight regions.

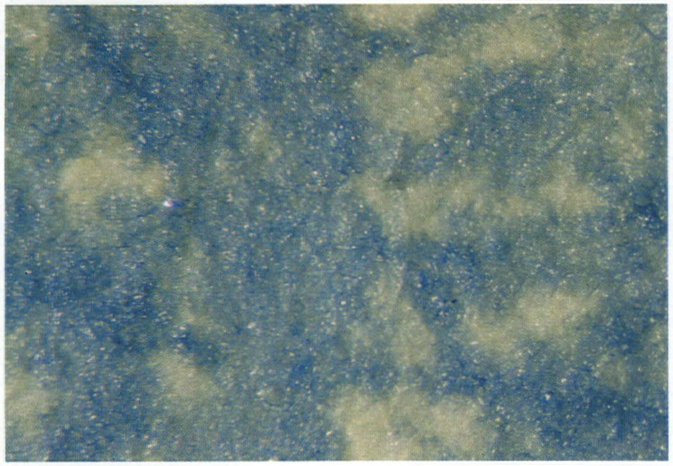


Fig. 5.8: Under the microscope, paper fibres are visible only in the highlight areas.

Fig. 5.9: This sample print has an apparent lack of contrast in comparison to a corresponding cyanotype print.

Encased Images: Daguerreotypes

Period of Use: Popular from the early 1840s to about the 1860s.

Structure:

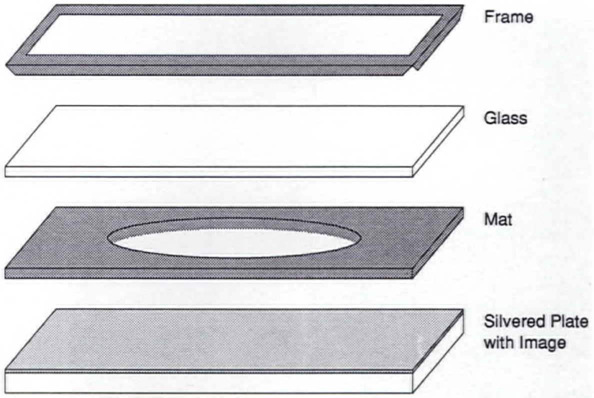


Fig. 5.10: The daguerreotype case is generally made up of many different elements that come together to form a method of display and act as a housing to prevent damage.

Fig. 5.11: A daguerreotype is a delicate-looking image that has a mirror-like surface.

Important Qualities:

- can appear negative or positive, depending on the viewing angle
- mirror-like surface
- sealed in a package with cover glass plate
- may be tarnished around the mat edges or overall
- usually presented in a protective hinged case
- decorative mat part of the normally sealed plate
- very delicate, easily damaged by touching the surface
- greyish-white deposit forms the image

Special Note: Over-exposure can produce an effect that appears as a bluish deposit in the highlight areas of the image. This is sometimes mistaken for applied colors.

Encased Images: Ambrotypes and Tintypes

Period of Use: Ambrotype processes were used from 1855 to about 1865. Tintypes were produced from the late 1850s to the 1930s.

Structure:

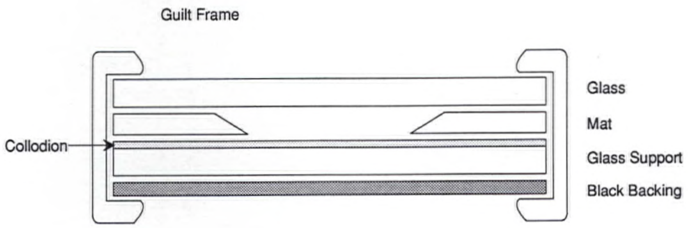


Fig. 5.12: An ambrotype consists of a collodion binder on a glass support. The ambrotype is presented in the same fashion as a daguerreotype. Viewed by transmitted light, an ambrotype appears as a negative.

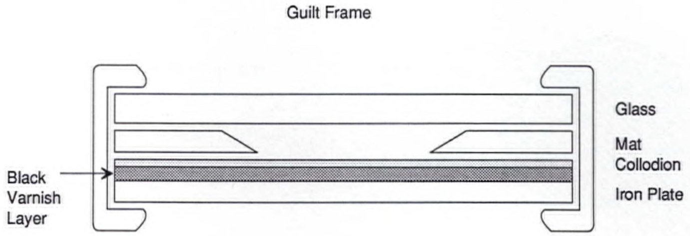


Fig. 5.13: A tintype is similar to an ambrotype except the support is lacquered iron instead of glass.

Important Qualities:

- creamy or greyish-white surface
- very flat in contrast
- sealed in a package with cover glass plate
- may be tarnished around the mat edges
- usually presented in a protective case
- decorative mat, part of the normally sealed plate
- often placed in paper window mats
- ambrotypes generally have a glass support
- tintype support is a thin sheet of lacquered iron
- a simple magnet will be attracted to the support (tintype)
- various black backing materials were used to give the positive appearance, including a painted on black lacquer or black paper or fabric

Special Note: It was not unusual to find ambrotypes with a deep red or purple glass support. The support can be seen by removing the sealed ambrotype from the case and viewing it by transmitted light.

Salted Paper Prints

Period of Use: The salted paper process was popular between 1840 and about 1855.

Structure:

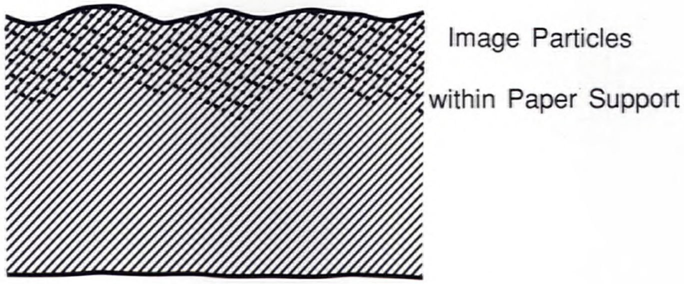


Fig. 5.14: This sketch shows the layer structure of a typical salted paper print.

Fig. 5.15: The image has very subtle characteristics (contrast, etc.) and the paper fibres are plainly visible.

Important Qualities:

- image can be reddish-brown (untoned), purple-black (toned) or yellow-brown (deteriorated)
- no binding agent
- no baryta layer
- paper fibres can be clearly identified
- various forms of deterioration visible (edge fading, image color)
- poor highlight detail
- no surface gloss
- poor overall sharpness
- poor shadow detail
- image appears to reside in rather than on the paper fibres

Special Note: The process has been revived and is used to some extent by fine art and some professional photographers.

Albumen Paper Prints

Period of Use: 1850 to about 1900.

Structure:

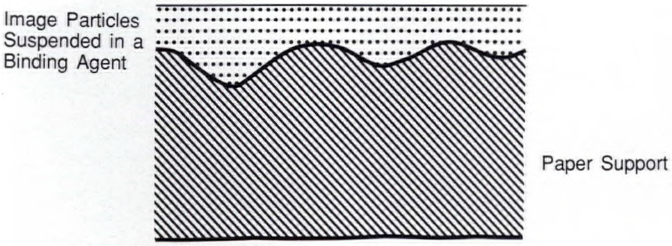


Fig. 5.16: A sketch illustrating the structure of an albumen print.

Fig. 5.17: Albumen paper print, in which the image is carried within the albumen layer.

Important Qualities:

- watermark may appear as part of the primary support
- has a binder layer made of albumen
- no baryta layer
- paper fibres can be seen throughout the albumen layer
- possible fading throughout image or in localized areas
- pristine albumen print is purplish-brown or purple
- uniform surface with no relief
- albumen layer may have tiny cracks and fissures throughout the image
- tendency of the albumen layer to yellow
- surface gloss can range from slightly glossy to very glossy

Special Note: The process has a support that is generally very thin. It was the dominant print medium for commercial photography between 1860 and 1895.

Ferric Processes: Cyanotypes

Period of Use: Occasionally produced during the period 1840–1860.

Structure:

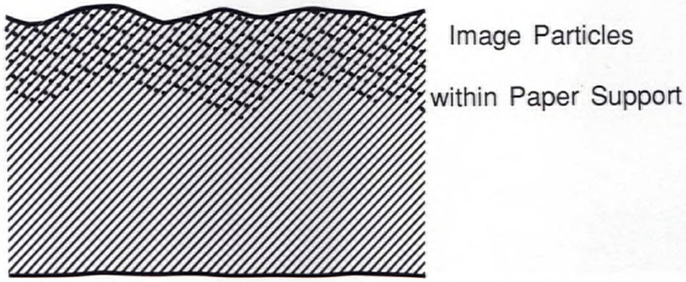


Fig. 5.18: A drawing representing the structure of a cyanotype.

Fig. 5.19: The blue color of the cyanotype makes it easy to identify. Very popular as a proofing material for amateurs.

Important Qualities:

- mat surface
- no binding agent
- no baryta layer
- paper fibres can be clearly identified
- various forms of deterioration are staining and embrittlement of the support
- severe fading of the image is uncommon
- bright, uniform blue color
- poor overall sharpness
- image appears to reside in rather than on the paper fibres

Special Note: Since this process does not have a binder, curling of the image is not a problem. Cyanotypes can be toned to various colors, but the toning is considered to be unpredictable and unstable (Crawford, 1979).

Ferric Processes: Platinotypes

Period of Use: Produced from the 1880s to the 1930s (also called platinum prints).

Structure:

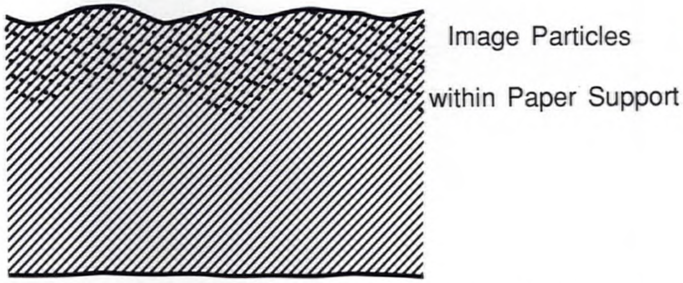


Fig. 5.20: Typical of a one-layer structure. The image is carried within the paper fibres as with a salted paper print.

Fig. 5.21: Platinotypes contain light-sensitive iron salts and a platinum compound that when developed give a print with very rich black tones.

Important Qualities:

- mat surface
- black or bluish-black image color (almost neutral)
- no baryta layer
- paper fibres can be clearly identified
- various forms of deterioration are quite rare, but do occur in the paper support
- "transfer image" may occur on a facing page or cover sheet
- fading of image is uncommon
- poor overall sharpness
- image appears to reside in rather than on the paper fibres

Special Note: It is possible to obtain a degree of control over the color of platinotypes today by controlling the humidity of the sensitized paper. Historically, printers lacked a method to control humidity, so the image was generally a bluish-black delicate looking picture (Ware, 1986).

Gum Dichromate Prints

Period of Use: Gum printing was never really popular until it was rediscovered by the pictorialists in the 1890s. The process is still being used today by a very few fine art photographers (Crawford, 1979).

Structure:

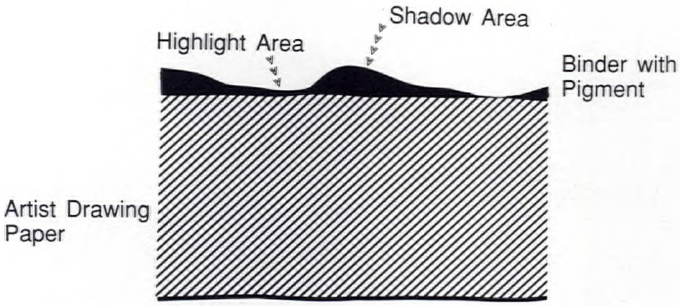


Fig. 5.22: Gum dichromate prints are produced by coating a piece of paper with a solution of gum arabic and potassium dichromate. When the paper is exposed to light in contact with a negative, areas that have received a great deal of light become insoluble.

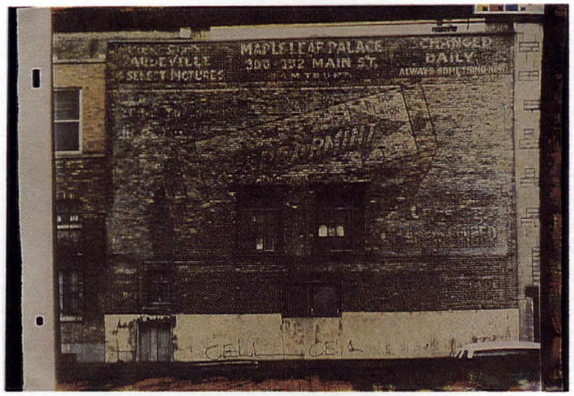


Fig. 5.23: Gum prints show very little resolution of fine details. Almost any pigment can be used as a colorant.

Important Qualities:

- mat surface
- excellent stability (depending on the pigment)
- no baryta layer
- paper fibres clearly visible in the highlight areas
- possible to see a "relief effect"
- varying thickness of the image layer (in dark areas there is a heavy deposit of pigment, but in the highlight areas there may be very little pigment or none at all)
- fading of image is uncommon
- possible to see particles of the pigment
- poor overall sharpness
- very flat overall contrast depending on the number of printings
- possible to see mis-registration lines if image is multi-colored or overprinted

Special Note: Gum prints are a very close relative to the carbon print process. They allow an enormous amount of manipulation and look like a watercolor print.

Silver Gelatin Prints

Period of Use: Used from the mid-1880s to present. The manufacture of printing-out papers in North America was discontinued in 1988.

Structure:

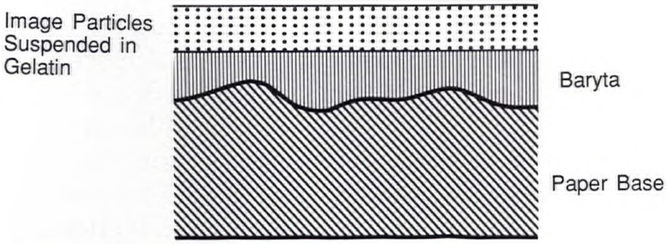


Fig. 5.24: Silver gelatin paper consists of three layers: image particles suspended in a binder, baryta, and a support layer.

Fig. 5.25: The surface of the silver gelatin print is moderately smooth and no paper fibres can be seen.

Important Qualities:

- many surface textures (mat, pearl, glossy, semi-glossy, etc.)
- generally tones are neutral, but various tones are possible
- between 1885 and 1895 some papers did not have a baryta layer
- paper fibres not visible because of the baryta layer
- deterioration can be in the form of silver mirroring, highlight detail loss, yellowing, overall fading, etc.
- continuous tone (no visible grain pattern)
- excellent overall sharpness
- generally good separation of tones in all parts of the image
- support may have manufacturer's stamp (backprint)
- printing-out papers are generally warmer in tone than developing-out papers

Special Note: Silver gelatin prints may not show any form of image deterioration and may have image colors and textures similar to other historical processes; it was not uncommon to chemically tone silver gelatin prints to look like other processes.

Identification by Cross-Section and Elemental Analysis

The second part of process identification is the examination of photographic images under magnification. An integral part of identification under magnification is the ability to make cross-sections. The production of cross-sections is a destructive method of material examination, but this type of scrutiny allows the student to analyse the structure of a photographic sample with a new perspective. Cross-sections should always be produced from photographic samples that have been slated for destruction.

There are several methods of preparing photographic samples for cross-sections. A very good technique involves embedding a small section of the photograph in a slow-hardening epoxy like Spurr's Embedding Epoxy. The procedure begins with prehardening, using a hardener such as Kodak Special Hardener SH-1, and then (without drying) dehydration with ethyl alcohol. The samples are then placed in an alcohol and epoxy mixture and eventually in 100% epoxy. After the epoxy has cured, the individual sample blocks are appropriately trimmed and cross-sections, on an ultramicrotome, are taken. Glass knives for producing cross-sections are used for light microscope studies, which enable the overall structure of the material to be examined (i.e., observation of the various layers). If a greater magnification is required, then a diamond knife is used to produce ultrathin sections that can be observed with a transmission electron microscope. This instrument allows the examination of the actual image particles at very high magnifications.

Finally, the identification of photographs through elemental analysis of the image particles may be performed using more sophisticated and modern techniques. Examples of such techniques are X-Ray Fluorescence Spectrometry (XRF) and Fourier Transform Infra-Red Spectrometry (FTIR). For XRF, a measurement of the wavelengths or energies and intensities from emissions by excited elements (excited by X-rays), is obtained, analysed, and plotted out in the form of peaks which identify the various elements. This technique is simple, rapid, and very versatile. Several types of instruments exist based on this principle. First, there are varieties that are destructive in the sense that sampling is required from the material. These instruments are capable of housing only limited sample sizes and thus some preparation for the analysis is required in many cases. They are available in stand-alone models or can be used in conjunction with scanning or transmission electron microscopes. An example of a non-destructive XRF technique is Radioisotope Excited X-Ray Energy Spectroscopy (REXES). Instruments using this technique are invaluable in the identification of unique or irreplaceable photographs since sampling is not required.

FTIR is a method of analysis that can be either destructive or non-destructive. In many cases, FTIR requires a very small portion of the photograph for analysis. It is used primarily for obtaining absorption spectra of organic compounds, but also for some inorganic substances. The infra-red radiation is absorbed by the sample's molecules and an absorption spectrum is produced. This method allows spectra to be measured faster and with a higher signal-to-noise ratio than regular infra-red instruments. When combined with an infra-red microscope, FTIR is known as Diffuse-Reflectance Infra-Red Fourier Transform Spectrometry (DRIFT) and is non-destructive to the sample. Sample size is not a problem as any size can be easily accommodated.

The ability to prepare samples for light microscopy or electron microscopy and access to the other advanced techniques, equipment, and expertise may not be available to most students. Nevertheless, we have included it because the knowledge gained by the ability to understand and recognize the structure of different photographic processes can give the student a real sense of how every aspect of the photograph is critical to its permanence.

Fig. 5.26: Cross-section of a contemporary salted paper print at a magnification of 120 times.

Fig. 5.27: Electron micrograph showing the distribution of silver particles in the paper support (5,000 times).

Analysis:

- can see the individual paper fibres
- image particles are suspended in the paper fibres
- no binding agent on the top of the paper support
- image particles are very small

Albumen Paper Prints

Fig. 5.28: Light microscope cross-section of an albumen print.

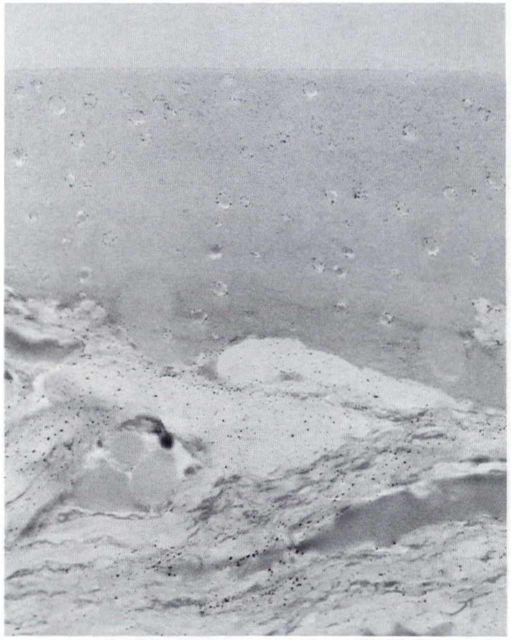


Fig. 5.29: Cross-section showing the top portion of an albumen print (4,400 times).

Analysis:

- albumen layer on the top of the paper support
- paper structure visible
- image particles suspended in albumen layer and paper support
- very small image particle size
- top of image layer very smooth (flat)
- more silver particles near the surface

Silver Gelatin (POP) Papers

Fig. 5.30: Cross-section of a silver gelatin print showing a maximum density area adjacent to a minimum density area.

Fig. 5.31: Electron micrograph of the layers of a silver gelatin print (6,150 times).

Analysis:

- image particles evenly distributed in gelatin
- baryta layer visible with large particles of barium sulfate
- baryta layer may not be part of the structure (early materials)
- image particles are small in size (spherical)
- baryta layer smoothes the surface of the paper support

Silver Gelatin (DOP) Papers

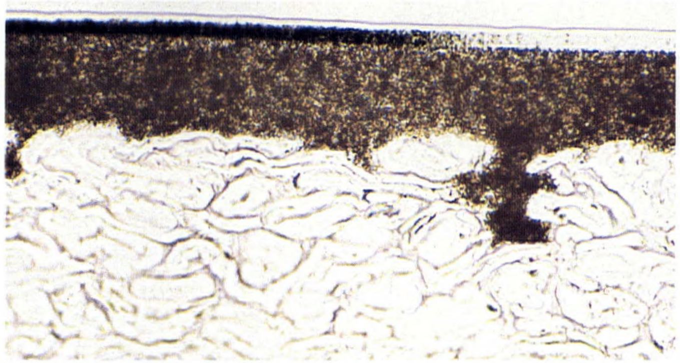


Fig. 5.32: Cross-section of a silver gelatin (DOP) paper.

Fig. 5.33: Electron micrograph of the structure of the developing-out paper grains (4,600 times).

Analysis:

- image silver grains are much bigger when compared to POP papers
- structure of modern paper image particles are clumps of filamentary silver
- particles are evenly distributed throughout the layer
- components of structure the same as POP papers
- very distinctive baryta layer (smoothes the barrier between paper support and image-carrying layer)
- thin layer of gelatin (overcoat) on the top of the image-carrying layer

Silver Gelatin (RC) Papers

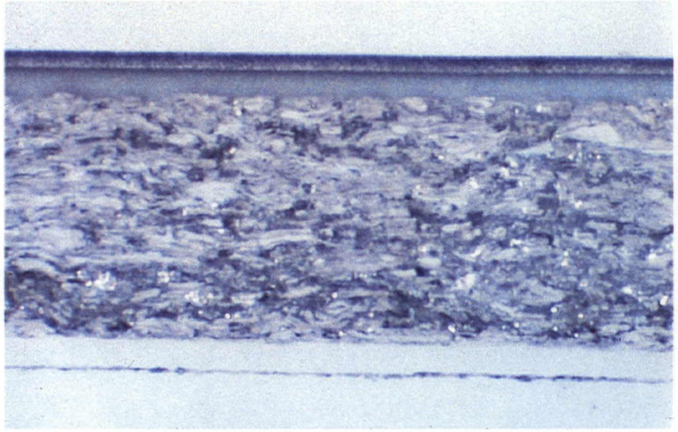


Fig. 5.34: Cross-section of a contemporary resin-coated paper. Compare the structure of this material with other silver gelatin papers.

Analysis:

- thin layer of gelatin (overcoat) on the top of the image-carrying layer
- image particles evenly distributed in binder
- silver particles noticeably larger than printing-out papers
- barrier between paper support and image layer is titanium dioxide in polyethylene (acts in the same manner as the baryta layer)
- paper support is sandwiched between very thin layers of polyethylene

Additive Color Processes: Autochrome

Fig. 5.35: Photomicrograph of an Autochrome plate.

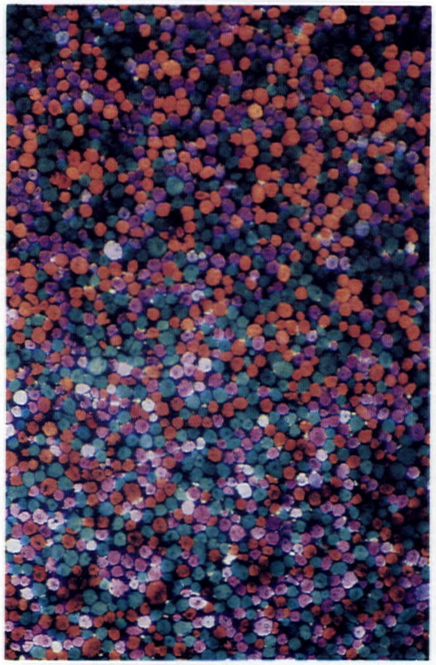


Fig. 5.36: Photomicrograph of the surface of a Lumière Autochrome plate, showing irregular arrangement of dyed starch grains.

Analysis:

- single layer of starch particles of the same size
- composed of red, green, and blue particles
- when viewed by projection, image appears flat and grainy
- primary support is glass
- area between colored particles is a black carbon material

Additive Color Processes: Omnicolore

Fig. 5.37: Photomicrograph of an Omnicolore plate.

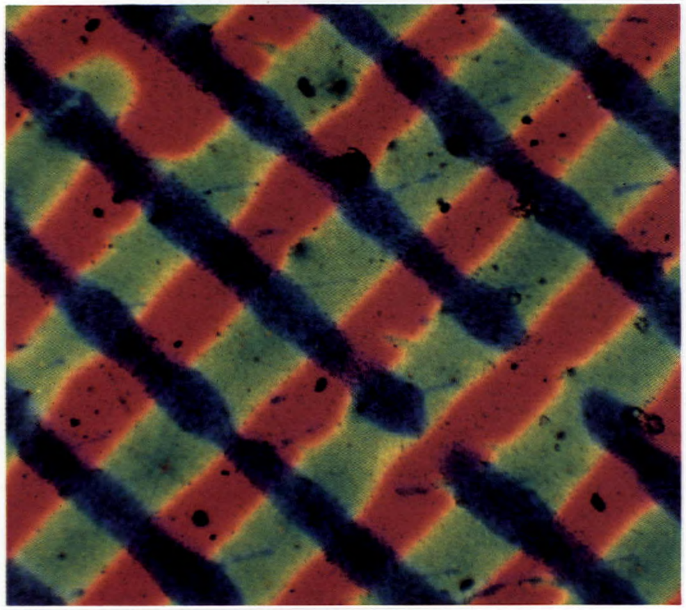


Fig. 5.38: Photomicrograph of the surface of an Omnicolore plate, showing the order of the colored lines.

Analysis:

- two parallel lines of red and green with a blue line crossing
- the blue line is positioned on top of the two other lines
- grain apparent
- image appears flat when viewed against contemporary color materials

Additive Color Processes: Dufaycolor

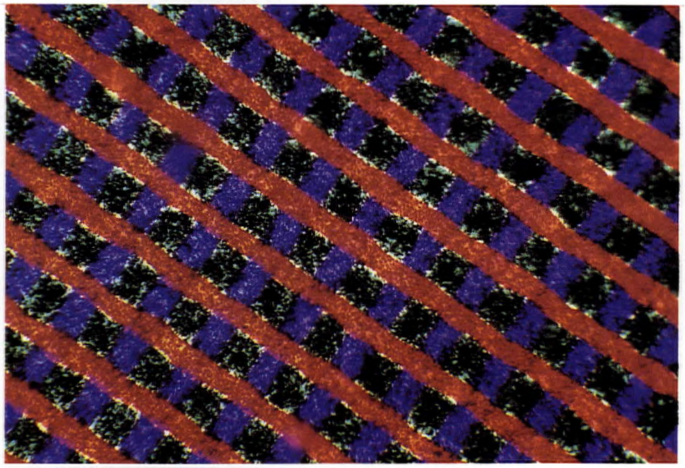


Fig. 5.39: Photomicrograph of the surface of a Dufaycolor plate, showing one type of regular screen pattern.

Analysis:

- small square elements of red, blue, and green arranged in a cross hatch pattern
- red will always appear to be on top with the blue lines next, followed by the green layer
- support is glass

Silver Dye Bleach Process: Cibachrome

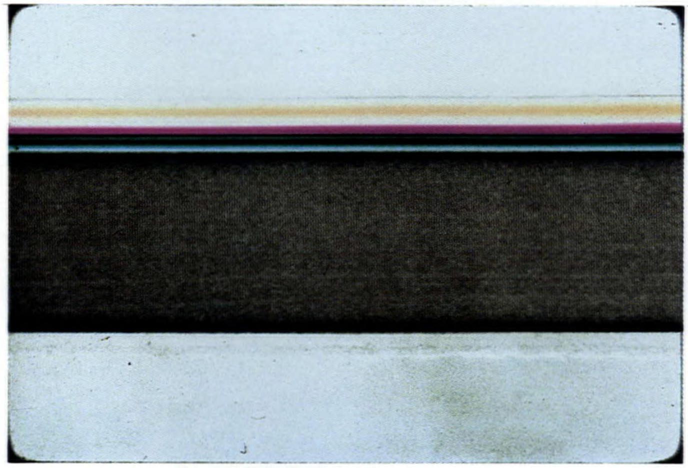


Fig. 5.40: Cross-section of a Cibachrome color print showing the dye layers.

Analysis:

- yellow dye layer on the top followed by magenta and then cyan layers
- has an overcoat material
- support is pigmented polyester
- anti-curl layer on the bottom of support

Chromogenic Process: Ektacolor 74 RC

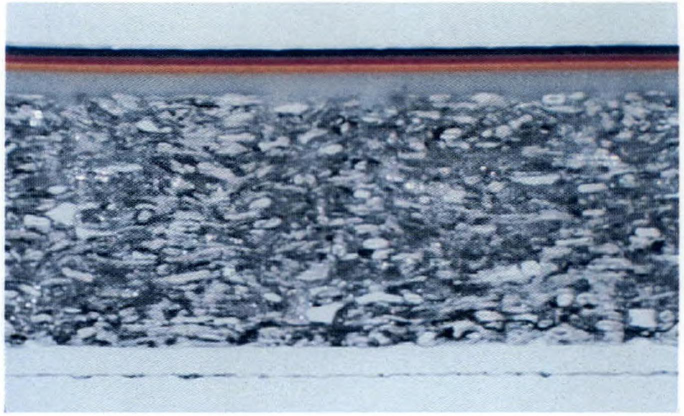


Fig. 5.41: Cross-section of a Chromogenic color print.

Analysis:

- cyan dye layer on the top followed by magenta and then yellow dye layers
- paper support sandwiched between polyethylene layers

Identification Testing Methods

Tests can be performed to further aid the student in identifying historical materials. These simple tests are a potential hazard to the photographs. When chemical solutions are used to assist in the identification process, the tests should be conducted by an experienced photograph conservator. Simple spot tests can distinguish between albumen, collodion, and gelatin processes. The method involves placing a drop of water or alcohol on a non-image area of a test print and allowing the solution time to react with the binder (60 seconds). Carefully blot the residual solvent from the photograph. Alcohol will not react with albumen but will dissolve collodion. If water is used, neither albumen nor the collodion print will react. If water is used on a gelatin print and if the binder is in good condition, the gelatin layer appears to swell when viewed at a low angle. In short, gelatin swells in water, collodion dissolves in alcohol, and albumen does not react to either (Eastman Kodak, 1985).

Because of the instability of cellulose nitrate film supports, their identification from other support materials, namely acetate or polyester, is crucial. The segregation of nitrate materials is necessary to prevent deterioration products of the nitrate films from affecting these other materials and also so that the nitrate negatives can be readily duplicated on safety base film before degradation destroys the image. Although some films are labelled as "safety film," many others exist that are not and, therefore, proper identification may be difficult. Consequently, several tests (Eastman Kodak, 1985) have been developed to distinguish between various support materials, but their results should be carefully interpreted. First, the float test is used to discriminate between nitrate-base film and polyester or acetate-base films. A margin of a film sample (non-image area) about 6 mm square is cut and placed in a test tube containing trichloroethylene (2/3 full). The tube is agitated so that the film sample is completely wet. If the sample sinks, it is nitrate-base film. If it floats, it is polyester or acetate material.

CAUTION: Trichloroethylene is toxic when inhaled. Perform the test under a fumehood and wear suitable gloves.

The second test is the burn test, which also distinguishes between safety film (acetate or polyester base) and nitrate-base film. A piece of the film sample approximately 3 mm × 25 mm is cut from a non-image area and held vertically from the bottom of the sample with tongs or tweezers. Using a match, ignite the film at the top of the sample. Film that burns downward completely in a rapid fashion with a bright yellow flame is nitrate film. A safety base material ignites only with difficulty and extinguishes itself fairly rapidly after the ignition and thus does not burn downwards.

CAUTION: Perform the test in the fumehood and ensure that all flammable materials and solvents are moved away from the testing area. Also, run the fumehood for a few minutes prior to testing in order to remove any lingering solvent vapors that may be present.

Third is the polarization test, which is used to differentiate between polyester and acetate film bases. Initially, a pair of "crossed" polarized filters are placed together and a reasonably strong light is projected through these filters. Then one filter is turned until the least amount of light passes through it. A strip of film or slide is placed between the two filters. When the light source is looked at again, there is no change with an acetate film base but polyester-based materials result in a lessening of the polarization effect and the creation of fringes of rainbow colors.

Other chemical solutions can give very specific results when it is necessary to identify a process. A bleaching agent for silver can detect whether the process is a silver-based process. The test is considered to be destructive, so please use this method with the utmost care! Place a small drop of a silver bleach, such as the Kodak Kodagraph eradicator, in a dark area of a test sample, allow the bleach to work for 15 seconds, blot, and observe. If the sample contains silver, the area should turn white or lighten in color. If no reaction has occurred, it can be concluded that it is a non-silver material. The bleached area of the sample can be converted back into black silver by placing a drop of developer in the same area that was bleached.

Another test that can distinguish between gelatin and albumen is a simplified test tube colorimetric method based on the Ehrlich's reagent (Eastman Kodak, 1985). The following tests are alternatives that give excellent results:

Spot Test for Silver Image (Eastman Kodak, 1974)

Solution A
potassium ferricyanide, 2 % solution

Solution B
sodium sulfide, 1.6 % solution

Procedure:

1. Bleach with Solution A.
2. Let droplet dry (do not blot off).
3. Stain with Solution B.

Comment: Solution A bleaches in some cases (albumen prints) very slowly. Solution B stains brown.

Spot Test for Cyanotypes (image color blue) (Eder, 1929)

Solution A
ammonium hydroxide, 3 % solution

Solution B
tannic acid, 2 % solution

Procedure:

1. Bleach with Solution A for 60 seconds.
2. Blot the solution off.
3. Stain with Solution B for 120 seconds.

Comment: The image should bleach to light yellow (ferric hydroxide). Solution B stains brownish-black.

Spot Test for Cyanotypes and Related Processes (image color blue)(Wächter, 1982)

Solution A
hydrochloric acid, 3.7 % solution

Solution B
potassium ferricyanide, 2 % solution

Procedure:

1. Bleach with Solution A for 15 seconds.
2. Blot the solution off.
3. Stain with Solution B for 60 seconds.

Comment: The bleaching time can be extended to 30 seconds if required. Solution B stains bright blue. (In case Solution A does not bleach but Solution B does, it is most likely a silver image.)

Microchemical Tests for Protein: Solutions and Procedures

Microchemical tests are destructive analytical methods. Although only a microscopic material sample is required, sampling should be performed only in areas where the loss of material is not significant and the aesthetic character of the examined work will not change.

These tests are very sensitive to any errors. Therefore the result is highly dependent on proper sampling. Take into account that the contamination of a sample from the image-bearing layer with traces from the paper sizing is possible.

Microchemical Test for Nitrogen (Schramm, 1982)
(This test is very sensitive and may be used to distinguish between proteins and carbohydrates)

1. Fill 1-2 mm of a capillary glass tube (0.4-0.5 mm) with calcium oxide (CaO) and push it about 15 mm into the tube using a very thin glass rod. Insert your microscopic sample (>0.1 µg) into the tube and fill it again with some CaO. Close the capillary tube on one side by melting one end.
2. In the open end of the tube, insert indicator paper and wet it with a drop of distilled water.
3. Heat the filled part of the capillary tube over the flame. If nitrogen is present, ammonium hydroxide is formed, which will cause the indicator paper to turn blue.

Microchemical Test for Sulfur (Schramm, 1982)
(Proteins contain sulfur-containing amino acids)

1. Insert a microscopic sample (>5 µg) about 15 mm into a capillary glass tube (0.4-0.5 mm). Close this end over the flame and insert on the open end a small Whatman filter paper strip which has been wetted in a saturated solution of lead acetate (**CAUTION – hazardous chemical**).
2. Heat the glass tube slowly over the flame until the sample is completely burned. If sulfur is present, the tip of the paper strip will turn a brownish-black (lead sulfide) color.

Microchemical Test for Albumen (Schramm, 1982)
(pyrrol derivatives)

1. Insert a microscopic sample (>2 µg) about 15 mm into a capillary glass tube (0.4-0.5 mm). Close this end over the flame and insert on the open end a small Whatman filter paper strip which has been wetted with a saturated solution of p-dimethylaminobenzaldehyde in glacial acetic acid.
2. Heat the glass tube slowly over the flame until the sample has been completely burned. If albumen is present, some fibres on the tip will turn from red to violet. Higher quantities of albumen will turn the whole tip red.
3. The reaction should be observed after some minutes under the microscope. During this time, keep the glass tube upright to allow the gases to reach the indicator.

5.1.3 Photograph Conservation Study Collection

Photographic images are found in many museums, galleries, and archives in a bewildering variety of types and sizes. As a student, it is important to practise and gain experience at looking at photographic samples that are properly labelled. Studying a collection of photographs that has been assembled as a reference tool is an effective method of quickly becoming familiar with the variety of historical processes.

Fig. 5.42: Example of the display method of the Photograph Conservation Study Collection of the National Archives of Canada.

A study collection is a collection of historical and contemporary materials. The collection should not limit itself to pristine photographic materials, but contain examples of a variety of common forms of deterioration, such as the appearance of image silver sulfide, staining from labels and storage enclosures, staining from improper processing, and the deterioration from built-in characteristics. As new products are introduced to the market, they can also be added to the existing study collection, thereby maintaining a chronology of photographic processes. Study collections should not limit their scope to prints, negatives, or transparencies, but should also include various types of packaging that accompany the materials. Packaging information is indispensable for instruction because it recommends how the material was intended to be used; it gives dates and other related information such as storage, expiry date of the material, and processing methods. Study collections allow the student to examine historical materials without the restrictions used for other photographs. Careful planning and organization of the various photographs in the study collection can greatly reduce careless or unnecessary handling by its users, which in turn gives a very effective learning tool.

The use of a study collection, in conjunction with the experience of making several kinds of historical printing processes and the study of the supplemental readings in this chapter, will provide the student with a good introduction to the methods of identifying historical and contemporary photographic materials.

5.2 Making Prints by 19th- and 20th-Century Photographic Processes

5.2.1 Experiment 1: Salted Paper Prints

Purpose

To produce salted paper prints, using several different kinds of paper, followed by a sensitometric evaluation of the products.

Introduction

Salted paper prints were the first fully developed process for producing repeatable photographic images. Calotypes (and the later Talbotypes) are, strictly speaking, the early salted paper negatives, from which salted paper prints were generated. (Very rarely, one will find albumen photographs made from a calotype negative.) One may also find reference to "calotype negative" and "calotype positive." Generally, the word "calotype" is used to specifically refer to the earliest of these images (usually negatives), and the terms "salted paper print" or "salt print" are used generically and interchangeably.

The calotype process was invented by William Henry Fox Talbot in England and presented to the public in 1841. His first image, a record made indoors of a latticed window in his house in Lacock Abbey, was made in 1835. In 1840, he produced his first positive images from calotype negatives (Brettell et al., 1984). The calotype procedure involved the use of a high-quality writing paper, treated in a solution containing chloride ions (most commonly from sodium chloride or table salt), dried, sensitized with a silver nitrate solution, dried again, exposed in camera, fixed, and finally washed. (Later, photographers discovered that the graininess of the paper could be suppressed and a sharper image produced by waxing the calotype negative before contact printing it.) A positive image was produced from this original negative by printing the paper negative in contact with another sheet of sensitized paper, and processed in the same manner. Calotypes, or salted paper prints, are thus made by a printing-out process. In 1851, L. D. Blanquart-Evrard of Lille, France, introduced a process for shortening the usually lengthy exposure time and then developing the exposed sensitized paper. Images made by his process were more nearly neutral black and white, and lacked the characteristic reddish tones of undeveloped calotypes (Coe, 1983). The variances in materials used, procedures followed, and results obtained were considerable, because of the experimental nature of this earliest kind of photograph on paper.

Salted paper prints found in collections today have often suffered and remain highly susceptible to damage from exposure to light, a result of the inadequate or altogether absent fixing of the image, at a time when the use of "hyposulfite of soda" to prevent the fading of photographic images on paper was at an early experimental stage. In a salted paper print, the elemental image silver rests directly on and among the paper fibres themselves, because there is no emulsion. The filamentary silver is very finely divided, making it quite susceptible to sulfiding, resulting in discoloration. The finest salted paper prints were produced from rather high-contrast negatives that had a very long density range, 1.70 or more, which resulted in a full range of tones, from the paper white to a visibly colored black or neutral black. (These colors result from the particular reflecting characteristics of the image silver, which in turn is affected by the particular materials and processing methods used to produce the image.)

Salted paper prints are relatively easy to make, but require great care at every step to avoid contamination and an uneven coating of the solutions. We have an advantage over 19th-century producers of salt prints, in that we have access to chemicals of the highest purity, a factor that photograph conservators should keep in mind when analysing the causes of deterioration in 19th-century salted paper prints. Several formulas for salted paper prints have been published in the 20th-century literature (Crawford, 1979).

Traditionally, a 100% cotton-rag paper of the kind intended for fine-art print making or watercolors can be used. Many varieties of "rag" paper (pure cellulose) are acceptable and are listed below, but we have found that these papers have very different characteristics. A sized paper is preferred for sharper images, to prevent the image silver from sinking too far into the paper fibres. If there is only one choice, our recommendation for a starting paper would be the Clear Print vellum.

Manufacturer's Name	Surface	Sizing	Weight (g/m²)	Notes
Arches Aquarelle	HP	Gelatin	300	Off White
BFK Rives	HP		270	Vélin Cuve
Cranes AS 8111	HP	Alum Rosin		Writing
Fabriano 2	HP	Gelatin		50% Cotton
BFK Rives		Gelatin	160	White
Pennshurst		Gelatin	160	Off White
Velin Arches	HP	Gelatin	80	
Clear Print	HP	Gelatin		Vellum

Fig. 5.43: Some suitable papers for historical printing.

Negatives

Negatives for most historical processes must have a relatively long density range, and they should have good separation in the shadow areas. Depending upon the characteristics of the paper versus salted paper formula, the paper requires a negative with a density range of 2.20 density units. This will give a full range of tones on the final print with good detail in the shadows as well as in the highlight areas. Since this process is produced by contact, the negative required must be the same size as the desired image. For further information on the method of producing enlarged negatives for contact speed printing processes, refer to Chapter 6 on Duplication and Copying.

Materials and Apparatus

- *Chemicals:*

  sodium chloride, 20 grams
  silver nitrate, 120 grams
  sodium thiosulfate, pentahydrate, 250 grams
  sodium sulfite, 20 grams
  gelatin, 2 grams
  sodium citrate, 2 grams
  T-53 gold toning formula chemicals

- *Papers:*

  4 kinds of high-quality artist's paper or writing paper, such as BFK Rives, Arches, Fabriano, or Clear Print:
  5 pieces of each kind, approximately 10" × 12"

- exposure template (step wedge, resolution target from Experiment 1: 4.2.1)
- contact printing frame
- light source: ultra-violet light tubes, 350 nm
- footcandle meter
- 8" × 10" pictorial negative (long density range)
- reflection/transmission densitometer
- prepared Kodak Curve Plotting Graph Paper
- balance
- graduated cylinder
- light-tight bottles, 500 mL
- magnetic stirrer
- blotting paper
- film dryer
- print washer
- film clips
- light microscope
- 5 Pyrex trays

Procedure

1. Cut the papers to fit the required negative or slightly larger. Write the name of the paper on the back of each sheet. Number each sample. The inscriptions on the back of each sheet are used to distinguish which side of the paper has been salted prior to sensitization. The inscriptions should represent the support side, so when you are preparing the paper you should see the markings.

2. Mix the chemicals according to the following formulas:

Salting Solution:

Sodium chloride	20 grams
Gelatin	2 grams
Sodium citrate *	20 grams
Distilled water to make	1000 mL

* Note: The sodium citrate is an addition to the original formula and changes the color of the image to a more reddish-brown.

CAUTION: Hazardous Chemical — Handle with Care — Avoid Contact with Eyes and Skin!

Sensitizing Solution:

Silver nitrate	120 grams
Distilled water to make	1000 mL

3. Traditionally, the salting and sensitizing solutions were brushed over the paper, but this technique tends to waste precious amounts of solution and requires great skill to avoid unevenness. One technique that produces a very homogeneous coating is with a tray (tray sensitizing). The paper is salted and sensitized by floating each sheet on the surface of the respective solution in an absolutely clean dish. Some practise is necessary in lowering the paper onto the surface of the solution. This can be accomplished by holding the paper from both upper corners, bowing the top, while at the same time lowering the bottom onto the solution first and then lowering the remaining part to drive out any air bubbles that could spoil the coating. Once the sheet of paper is floating on the surface of the solution, a spray gun (atomizer) dispensing a mist of distilled water can be used to "relax" the paper. Care should be taken to avoid any of the sensitizing solution getting on the back of the paper, otherwise it will be desensitized at this point. The paper should be allowed to float for three minutes in each solution (sodium chloride and silver nitrate solutions). The paper can be removed from the tray by slowly drawing one corner away from the tray. This can be easily accomplished by clipping the corner of the paper with a Kodak film clip. The second corner is clipped as the paper is being lifted away from the tray. As excess solution drips back into the tray, two additional film clips can be attached to the bottom of the sheet of paper. The paper is placed into the dryer and inverted to even out the coating. It is possible to prepare the paper under subdued light (15-watt bulb), but we have found that the best light source is a sodium vapor type safelight.

4. Using the exposure template and an ultra-violet light source (**use suitable eye protection**), make prints on each of the four different paper types. The prints will lose density while in the fixing bath, so be sure the

print is sufficiently well-exposed, resulting in the lightest step of the step wedge having received enough exposure so that it appears to be heavily over-exposed. It may be necessary to expose two or more pieces of paper before the correct exposure is found. Record the exposure time and light intensity in footcandles on each sample (depending on the type of light source).

5. Treat the samples in the ANSI Non-Hardening Fixer (four minutes in one bath) (see Section 4.3.6), followed by a 20-minute wash in the archival print washer. Gently blot the prints and air dry them on screens (face up).

6. Take density readings — visual, red, green, blue — and plot the characteristic curve for each type of paper. Determine the effective density range and log exposure range. Read the resolution targets using the light microscope.

7. Determine the density range of the 8" × 10" pictorial negative. For each type of paper, determine the correct exposure time (refer to Section 4.2). Expose and process two prints for each of the four paper types. Expose and fix a second exposure template for each type of paper.

8. Treat one print from the modulator samples and one from the pictorial negative, for each of the four paper types, in the Kodak Gold Toning Formula T-53, published in the Photo-Lab Index (Lifetime Edition), by Morgan & Morgan, which gives a POP toner formula from Kodak Limited (England):

   For Salted Paper Prints:

Stock Solution A	
Ammonium thiocyanate	10 grams
Distilled water to make	500 mL
Stock Solution B	
Gold chloride	1 gram
Distilled water to make	500 mL
Working Solution	
Solution A	15 mL
Solution B	15 mL
Distilled water to make	500 mL

   After the exposure time, the print must be washed in distilled water for 10 minutes. The wash water should be changed frequently (seven times) and agitated continuously. Subsequently, the print is placed in the gold toning solution for 10 minutes with gentle agitation and then washed for two minutes in distilled water. After this, the print can be processed in the normal manner for untoned salted paper prints.

9. Take density readings of the gold-toned samples for each paper and read the resolution targets. Plot the characteristic curves as described in step 6 above.

Analysis

Make a visual and sensitometric evaluation of the effect of the gold toner on the processed prints, as compared to the untoned prints.

Evaluate the sensitometric and visual differences between the various paper types and compare the resolution values.

Questions

1. How long can you store sensitized paper?
2. Is it really necessary to use distilled water in the preparation of the sensitizing solutions?
3. How much solution is necessary for preparing the prints?
4. Is it possible to develop salted paper prints?

5.2.2 Experiment 2: Albumen Prints

Purpose

To produce an albumen print and subsequently evaluate the characteristics of the print using sensitometry.

Introduction

In 1850, after a period of 10 years of salted paper print popularity, a Frenchman, Louis Désiré Blanquart-Evrard, introduced a process involving the suspension of metallic silver in a binding medium. This binder consisted of albumen or egg whites. The process involved the separation of egg whites from the yolks and denaturing of the protein. This was necessary because the consistency of albumen (without denaturing) was not suitable for coating. Thus, coating evenly was an extremely difficult task. Denaturing produced a more homogeneous liquid that resulted in easier and more even coatings. Very high quality and thin papers were used for this process. The albumen coating smoothed out the paper surface, filling any pores and creating photographic prints with glossy surfaces. Addition of sodium or ammonium chloride to the albumen and sensitization with silver nitrate, as with salted paper prints, enabled an image to be formed that was suspended above the paper layer.

The popularity of albumen prints spread rapidly worldwide after their introduction. From 1855 to 1895 it was the dominant photographic process. This material possessed certain characteristics that made it a much more desirable product (than salted paper prints) for the amateur and professional photographers of that time. Greater contrast and density in prints were obtained along with crisper or sharper images with fine detail being obtainable. It could also be toned, which became a common practice. A wide variety of tones, as with salted paper prints, could be obtained, changing reddish-brown tones to purplish-brown or blue-black ones. In addition, (after 1870) certain dyes of pink, blue, or violet were commonly added to the albumen solution prior to coating, which served to mask the yellowing of the albumen layer and provided a pleasant visual effect.

Albumen papers, however, are not without problems. Today, albumen prints are suffering from various degrees of fading and staining. This was probably the result of the permeability of the albumen layer. Washing was difficult as a result, and the retention of thiosulfate used for fixing was inevitable, leading to a reaction with the silver image and subsequent fading or staining. Also, atmospheric pollutants have contributed to this degradation. A characteristic yellowing of albumen prints in the highlights and non-image areas also is a problem. This is due to silver albumenate (Reilly, 1986). This complex is formed during the sensitization step. Silver binds very strongly with sulfur containing groups of the albumen and, therefore, fixing does not remove this silver. As time passes, silver sulfide is formed resulting in the yellowing. Finally, coated albumen becomes brittle with age and cracks or fissures develop.

Some of these shortcomings became apparent around 1900 and the inconvenience of having to sensitize the paper before use led to the decreased popularity of albumen. The emergence of gelatin and collodion printing-out papers evolved, since they could give a wider range of surfaces, image colors, and better image stability, and were ready for use.

Materials and Apparatus

- fresh eggs, 1 dozen
- Clear Print paper — an art paper
- chemicals for albumenizing solution
- chemicals for sensitizing solution
- ANSI Non-Hardening Fixer
- Kodak Hypo Clearing Agent
- exposure template (step wedge, resolution targets from Experiment 1: 4.2.1)
- prepared Kodak Curve Plotting Graph Paper
- light box, containing ultra-violet light tubes, 350 nm
- contact printing frame
- print washer
- reflection densitometer
- beaker, 4 liters
- Pyrex trays, 12" x 18"
- Pasteur pipette
- atomizer
- film clips
- safelight conditions
- light microscope
- film dryer
- stirrer
- squeegee

Procedure

1. Prepare the albumenizing solution by first separating the egg whites or albumen from the yolks. The recommended procedure is a two-beaker system in which an egg is cracked in two and the egg white is decanted into a beaker. Gently passing the yolk from one half of the eggshell to the other allows for better removal of the albumen. Once this has been performed, the albumen just separated is checked for any impurities, namely eggshells or some yolk. Then the albumen is transferred to the main beaker if it is clear. By treating the eggs one by one in this manner, contamination of the albumen previously separated will not occur as a result of a subsequent poorly separated egg. If an egg white has been contaminated, try to remove the source of the impurity using a Pasteur pipette or simply discard the albumen. Measure the volume of albumen collected.

2. Prepare the following albumenizing solution in a 4-liter beaker:

   Albumenizing Solution:

Sodium chloride	15.0 grams
Glacial acetic acid	2.0 mL
Distilled water	30.0 mL
Albumen	1.0 liter

   Adjust quantities for the amount of albumen collected.

3. Mix the albumenizing solution with an electric stirrer. The solution should be stirred vigorously, allowing the liquid to be converted to froth. Mixing should be performed for about two hours.

4. Cover the solution and let it stand for 24 hours.

5. After the waiting period, remove the froth that is on top of the settled-out liquid (without disturbing the liquid), making sure that most, if not all, of it is removed.

6. Pour the solution into the Pyrex tray so as to cover the bottom. Drag a piece of paper on the solution to remove any bubbles or froth on the surface. Discard this sheet. Next float another sheet by laying the middle of one side of the paper (which has been marked with an HB pencil in one of the corners) on the solution first and then the remaining middle section to the other end. The ends of the paper are then gently laid on the surface of the solution. The back of the paper is immediately sprayed lightly with an atomizer, filled with distilled water, to prevent curling. At this point any trapped air bubbles may be removed by gently lifting the ends of the paper and lowering them again slowly. Float for three minutes. Lift the paper slightly from both ends of one side very slowly. Continue

to slowly lift the paper off the solution, letting the excess albumen run off as the paper is being lifted. This lessens the probability of an uneven coating. Hang in a film dryer by two corners and attach clips on the bottom two corners to prevent curling while drying. Dry at moderate heat (approximately 40°C).

7. Prepare the following solution:

   Sensitizing Solution:

Silver nitrate	60.0 grams
Distilled water	500.0 mL

   Pour enough solution in the tray to cover the bottom.

8. *Under safelight,* place the albumenized sheet (the marked side facing the solution) on the solution as described in step 6. Float for three minutes, lift slowly from the solution and hang to dry as described in step 6. Avoid getting any solution on the back of the print.

9. Place the exposure template in contact with the sensitized paper, emulsion to emulsion, in a contact printing frame. Expose using an ultra-violet light box or other suitable light source, until the print appears slightly overexposed. (**CAUTION: Use suitable eye protection.**) The exposure can be monitored by removing the print frame from the ultra-violet light source and opening half of the printing frame so that the paper is still secure. Gently lift half of the sheet to look underneath.

10. Remove the print from the printing frame, fix in ANSI fixer for eight minutes (two baths of fixer four minutes in each), rinse in water for one minute, bathe in hypo clearing agent for two minutes and wash for twenty minutes. Lightly squeegee the back of the print and lay flat to air dry.

11. Take visual and tricolor density readings of the grey scale and plot the visual readings on the prepared curve plotting graph paper. Read the resolution targets using a light microscope.

Analysis

Comment on the shape of the characteristic curve. Compare this process with the one for salted paper prints in terms of density ranges, gamma, resolution, log exposure range, image sharpness and tone, and the two procedures overall.

Questions

1. What three elements in this procedure are participating in the denaturing of the albumen and why is it necessary?
2. Explain some of the advantages and disadvantages of having the silver suspended in albumen as opposed to being embedded in paper fibres as for salted paper prints.
3. What are some of the signs of deterioration that enable the identification of historical albumen prints?
4. Why is the image overprinted?

5.2.3 Experiment 3: Cyanotype Prints

Purpose

To practise techniques that produce cyanotypes, using a variety of papers, and examine the results using sensitometric principles.

Introduction

The cyanotype process was first described by Sir John Herschel in 1842. Herschel used various ferric salts (ferric chloride, ferric ammonium citrate, and potassium ferricyanide), the photosensitivity of which have been observed earlier. These iron salts are reduced by light to a ferrous state. They then combine with other salts to produce an image.

One of the first to use the process on a large scale was Anna Atkins (a friend of W.H.F. Talbot) in her privately published book, *British Algae: Cyanotype Impressions* (1843, a three-volume work meant to include 389 pages of captioned plates)(Schaaf, 1982). This was the first published botanical catalogue to use photographic illustrations. One occasionally finds early photographically illustrated books that used tipped-in or pasted-on cyanotype plates.

By the 1890s, the cyanotype process had attracted the attention of amateur and commercial photographers, primarily because iron salts, being less expensive than silver salts, could be obtained cheaply, and so the supplies for producing cyanotypes were not costly. Commercial blueprint papers were available in the late 19th century and still are available for use in copying architectural drawings.

The most widespread use of the cyanotype was as a proof-printing method for glass negatives. The cyanotype was not considered a desirable print in itself, but only an inexpensive means to help the photographer choose the negatives from which to make final (albumen, platinum, or silver gelatin) photographs.

Although 19th-century practitioners found the blue color intrusive, some photographers today exploit the process for that very quality.

Negatives

The printing characteristics of the cyanotype process are not unlike other historical printing-out processes. Negatives made to print using this process should be of the same size as the desired final print size. The negative should have a density range of approximately 1.10 or more. It is possible to increase the printing contrast by adding potassium dichromate to the sensitizer. Generally, a light source with a high ultra-violet content produces a cyanotype print with a printing contrast similar to a grade 0 contemporary enlarging paper.

Paper

Any number of paper types or linen material is acceptable for cyanotype printing. Acceptable results have been obtained using a white linen material from a corner clothing store. Generally, the types of papers that work best are well sized and relatively smooth. Very nice prints can be obtained using heavily textured surfaces without any sizing material.

Materials and Apparatus

- *Chemicals:*

    ferric ammonium citrate, 20 grams
    potassium ferricyanide, 8 grams
    hydrogen peroxide (3% solution), 20 mL
    potassium dichromate (1% solution), optional

- *Papers:*

    choose 4 different kinds of high-quality unbuffered artist's paper or writing paper, such as Arches, Johannot, BFK Rives, Fabriano, or Saunders, 10" × 12" sheets

- exposure template (step wedge, resolution targets from Experiment 1: 4.2.1)
- light source: ultra-violet light tubes, 350 nm
- footcandle meter
- contact printing frame, 11" × 14"
- pictorial negative (long density range), 8" × 10"
- reflection densitometer
- prepared Kodak Curve Plotting Graph Paper
- balance
- glass stirring rod
- large soft brush, 2" × 3" wide
- graduated cylinder
- light-tight bottles
- 2 glass developing trays or glass dishes
- magnetic stirrer
- blotting paper
- light microscope

Procedure

1. Cut paper to desired sizes. Eight samples in total are needed to accommodate the exposure modulator and 8" × 10" negative. Label each as to the kind of paper. Number each sample. In a room with subdued light, lay out blotters on which the sensitized paper can be laid for drying.

2. Be sure that all containers, brushes, stirring rods, and other equipment are clean. Cyanotype solutions contaminate very easily.

3. Mix cyanotype Solutions A and B, according to the following formulas:

    Solution A

Distilled water	50 mL
Ferric ammonium citrate (green)	20 grams
Distilled water to make	100 mL

    Solution B

Distilled water	50 mL
Potassium ferricyanide	8 grams
Distilled water to make	100 mL

Store in brown bottles or away from light.

4. Sensitization should take place in a darkroom, illuminated by no more than a 15-watt bulb. In this section there are three methods for sensitizing papers. Sample all three methods, but choose one to produce the eight test samples. Brush the solution onto the paper samples, using a large soft-bristle brush. Immediately before use, combine Solutions A and B in a glass developing tray or dish. Keep lots of solution on the brush. Brush in both directions to ensure an even coat. Allow the excess to drip off one corner, then rotate the paper to even out the coating. An alternative method to brushing the paper with the sensitizing solution is to float the paper on a thin solution in a tray. The method is the same as described for sensitizing salted paper prints. Another method that uses very little solution uses a glass rod to push the sensitizer over the paper surface. The paper can be taped to a glass sheet where the glass rod is placed at the top of the paper. The rod can be held in place by putting two small lead weights at either ends of the rod. A pipette is used to spread the solution along the glass rod (without rolling it), creating a bead large enough to coat the whole sheet of paper (refer to Figure 5.44). It may be necessary to move the rod across the paper twice to secure an even coating, but a word of caution — too many attempts to obtain a homogenous coating could lead to undesired effects.

5. Prepare all eight samples using one of the methods already described. Lay them onto fresh, flat blotters and allow them to dry under subdued light conditions. The solution will appear bright yellow on the paper and will remain yellow when dry.

6. Measure the illumination of the light source in footcandles if possible. Under subdued light and by contact, expose one piece of each of the paper types, using the step wedge (template). Record all exposure times. Expose the print until the first four steps of the template look as if they have been overprinted. The shadow areas will appear as if they are reversed; this is normal. Following exposure, the D-max areas will appear washed out (lighter in tone) and the highlights will be slightly cloudy.

7. *In subdued light,* wash the exposed prints in a water bath for five minutes (20°C) to clear the highlights and to remove soluble ferric salts from the image, which could cause fading upon exposure to light. Change the water bath once every minute.

8. Following washing, place the prints in an oxidation bath. This will rapidly deepen the tones considerably.

Oxidation Bath:

Distilled water	100 mL
Hydrogen peroxide (standard 3% solution)	20 mL
Distilled water to make	200 mL

9. Wash the prints for five minutes. Gently blot and air dry them.

10. Read the visual densities using the step wedges, plot the curves, and determine the density ranges and log exposure ranges for each of the four different paper types. Read the resolution targets using the light microscope.

11. Determine the density range of the 8" × 10" pictorial negative. Sensitometrically determine the correct exposure time for the negative. Repeat for each of the four paper types the printing, washing, and oxidation bath procedures, as followed for the exposure template samples. Dry the pictorial samples as above. Determine the density range of the pictorial cyanotype prints (Section 4.2).

Analysis

Make a visual analysis of the pictorial samples. Which produces the most satisfactory image? What accounts for the differences among the samples? Comment on the sharpness of the various paper types.

Question

1. What is it about this process that made it popular for use by studio and pictorial photographers in making proof prints from glass negatives?

5.2.4 Experiment 4: Platinum Prints

Purpose

To introduce to the novice preparation techniques used for platinum prints, followed by the evaluation of the samples using standard sensitometric principles.

Introduction

Platinum prints have always piqued the interest of photographers, not just for their durability, but also for the beautiful range of tones that they possess.

William Willis from England is considered the inventor of the platinotype. On June 5, 1873, he introduced his new "photographic printing process" (patent No. 2,011). During the next years, Willis continually improved the process and the later patents are a reminder of his interest. By the late 1800s, it was widely recognized that silver images were not permanent. Willis also understood the limitations of the silver processes and began his investigation into other metals. After overcoming many problems, Willis was granted his first patent in 1873. Willis also founded The Platinotype Co., which first offered for sale in 1880 "hot developer papers," resulting in the introduction of a "cold developer paper."

The chemistry of platinum printing involves the use of light-sensitive iron salts. Basically, a suitable paper type is sensitized with a solution of ferric oxalate and potassium chloroplatinite and is then exposed. Irradiation by light leads to the reduction of the ferric salts to ferrous salts (which are good reducing agents) and enables development to occur. The developer consists of potassium oxalate. This substance dissolves the ferrous salts, enabling sufficient contact with the chloroplatinite and allowing reduction to platinum metal to proceed. Any remaining light-sensitive ferric salts after development are made soluble and removed by immersing the print in a dilute hydrochloric acid solution. The metallic platinum that forms the image is a very noble metal (i.e., chemically inert), resulting in prints that are extremely stable to image deterioration.

With the increase in the price of platinum and palladium salts (a later alternative salt), platinotype papers very quickly disappeared from the market, replaced by other cheaper enlarging speed papers. Yet, in some ways it is nice to see the reappearance, brought on by today's "art photographers," of the extraordinary qualities that platinum prints possess.

Materials and Apparatus

- *Chemicals:*

ferric oxalate	30 grams
oxalic acid	2 grams
potassium chlorate	0.3 gram
potassium oxalate	500 grams
hydrochloric acid 37%	7 mL
distilled water	2 liters
potassium chloroplatinite	10 grams

- *Papers:*

  4 kinds of high-quality artist's paper or writing paper, such as BFK Rives, Arches, Fabriano, or Saunders, 5 pieces of each kind, approximately 10" × 12"

- exposure modulator (step wedge, resolution targets from Experiment 1: 4.2.1)
- contact printing frame
- light source: ultra-violet light tubes, 350 nm
- footcandle meter
- pictorial negative (long density range), 8" × 10"
- reflection densitometer
- prepared Kodak Curve Plotting Graph Paper
- balance
- glass stirring rod
- graduated cylinder
- light-tight bottles, 100 mL
- thermometer
- magnetic stirrer
- blotting paper
- sheet of glass, (11" × 14")
- glass rod (slightly larger than largest print)
- latex gloves
- drying cabinet
- print washer
- Pasteur pipette
- 4 Pyrex glass trays

Procedure

1. Gather the selected papers and cut them to the desired size. Write the name of the paper type on the back of each sheet. Number each sample.

2. Assemble the glassware and containers suitable for storing and mixing platinum solutions.

3. Mix the chemicals according to the following formulas:

The safety of both yourself and other workers must be a prime concern when working with chemicals. Be aware of potential health hazards at all times. It is expected that persons using chemicals are cautious and considerate of the dangers posed by toxic chemicals that are used in these experiments.

The Sensitizer:

Solution 1

A. Distilled water (45°C)	55 mL
B. Oxalic acid	1 gram
C. Ferric oxalate	15 grams

Solution 2

A. Distilled water (45°C)	55 mL
B. Oxalic acid	1 gram
C. Ferric oxalate	15 grams
D. Potassium chlorate	0.3 gram

Solution 3

A. Distilled water (38°C)	50 mL
B. Potassium chloroplatinite	10 grams

Mixtures for Contrast Control:

I. To produce a normal print from a very soft negative:

Solution 1	0 drops
Solution 2	22 drops
Solution 3	24 drops

II. To produce a normal print from a soft negative:

Solution 1	10 drops
Solution 2	12 drops
Solution 3	24 drops

III. To produce a normal print from an average negative:

Solution 1	**14 drops**
Solution 2	**8 drops**
Solution 3	**24 drops**

IV. To produce a normal print from a high contrast negative:

Solution 1	18 drops
Solution 2	4 drops
Solution 3	24 drops

V. To produce a normal print from a very high contrast negative:

Solution 1	22 drops
Solution 2	0 drops
Solution 3	24 drops

It is possible to modify the proportions of the three solutions for individual tastes and types of negative contrasts. We have not investigated mixtures other than those listed above.

4. The traditional method for preparing the paper was to brush the sheet of paper with the sensitizing solution. This method has been proven to waste precious amounts of the valuable metal and does require a certain skill to be successful. Michael J. Ware describes a method that works well. The technique uses a glass rod to spread the solution down the length of the paper. He states:

"A more economical method, giving very homogeneous coatings, was used for the present experiments: the sheet of paper is clipped or taped to a flat glass plate and a suitable volume of sensitizer (see below) is expelled from a small (1 or 2 cm^3) hypodermic syringe (without needle) in an even line across the top of the paper; the solution is then spread by drawing it down the length of the paper using a glass rod of length equal to the desired coating width. The rod is not rotated, but the "line" of sensitizer is drawn up and down the paper, with very little pressure, slowly and evenly several times (at least three, but more than six offers no additional benefit)" (Ware, 1986).

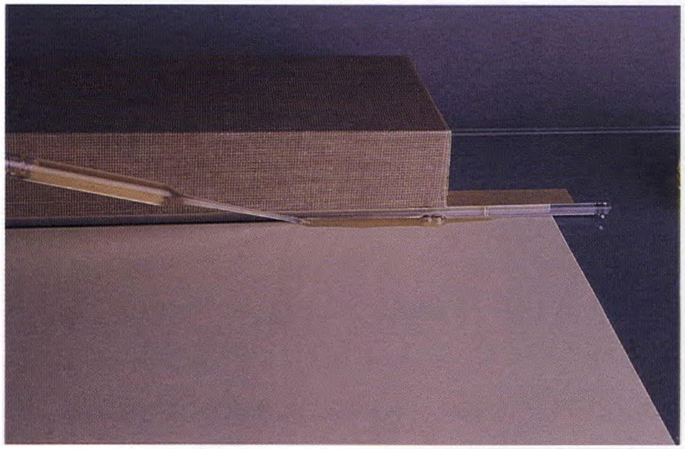


Fig. 5.44: Example of a technique that uses a glass rod to spread the solution across the paper.

5. Prepare all the samples in this manner. Hang them in a drying cabinet or onto fresh, flat blotters and allow them to dry in total darkness. Drying under dry heat (38°C) in a commercial film dryer for 15 minutes can be done as long as the paper is allowed to rehydrate to a desired printing humidity. It is apparent from Ware's discussion that for optimum performance of a sensitized paper the relative humidity in the paper should be around 55%. This will give the paper good speed, with warm blacks and a $\Delta \log H$ of 1.20.

6. Set up the ultra-violet light source (custom-built printer using fluorescent F20T10BL bulbs) or an alternative light source that gives off a substantial amount of ultra-violet radiation. In an area with subdued light, expose one piece of each of the paper types in a contact frame, using the prepared step wedge. Record all printing information and observations. Since this is a developed-out process, trying to calculate exposure by observing the degree of print-out is difficult. As a guide, exposure should be enough to give a perceptible density in the shadow areas. The only method that will give good results is to make test strips with the template and plot the data.

7. In a room with subdued light, assemble four Pyrex glass trays that can accommodate the dimensions of the exposed platinum print. The exposed print should be developed right away in a saturated solution of potassium oxalate.

Distilled water (25°C)	1363 mL
Potassium oxalate	454 grams

   Slip the exposed paper sample into the developer as quickly and smoothly as possible. If the developer does not cover the entire surface of the paper in a continuous rapid manner, irregular marks can occur. Develop until there appears to be no more development; this should take less than one minute.

8. The samples can be cleared by placing the prints in three successive acid baths containing diluted hydrochloric acid.

Distilled water	420 mL
Hydrochloric acid (37%)	7 mL

   Using tongs, place each sample in each acid bath for five minutes, agitating every minute. As the first acid bath begins to discolor, properly dispose of the first and move the second bath into the first bath location and so on. Renew the empty tray with a fresh acid solution.

9. After the clearing, wash the prints in an archival print washer for 20 to 30 minutes. Air dry the print either in a forced-air cabinet or on archival type drying screens.

10. Take visual and tricolor density readings and plot all the data. Determine the specific printing characteristics of the various paper types. Using the light microscope, read the resolution targets (see Chapter 4).

11. Repeat steps 1 through 9, using an 8" × 10" pictorial negative and information obtained from your test samples.

Analysis

Make a visual analysis of the print step wedges and the pictorial samples. Look at the characteristic curves of the platinum wedges and compare them against one another. Ask yourself what accounts for the small differences in color. Also compare the curves and the resolution targets with the other samples.

Question

1. Is it possible to get different tones?

5.2.5 Experiment 5: Gum Dichromate Prints

Purpose

To practise methods that will produce gum dichromate prints, and analyse these samples with sensitometric principles.

Introduction

Gum dichromate printing is a relatively simple process and, when viewed, is much like looking at a watercolor drawing. A Frenchman, Alphonse Louis Poitevin, is credited with inventing the pigment printing process in 1855. Others, such as Vauquelin (1798), Suckow (1832), Ponton (1839), and Talbot all contributed their observations, which resulted in the success of the various dichromated processes.

The extreme flexibility of the process has attracted photographers who believe that no other photographic process can be manipulated to such an extent as the gum dichromate process. A photographer can choose his own colors and can alter the contrast of prints through multiple coatings and exposures. Also, the prints can be altered after exposure, either before or following development. The image can be etched to remove any undesirable effects or in-painted. The permanence of the print is excellent if the proper pigments are chosen, i.e., those that resist reactions with light, moisture or atmospheric pollutants. Because of this, the gum dichromate process is perhaps most responsible for the renewed interest in other more exotic historical processes.

The dichromate process is not unlike other photographic processes in that this process is also affected by the action of light, although it is not as sensitive as the silver halide process. The procedure involves the use of three main components: gum arabic, watercolor pigments, and ammonium or potassium dichromate. Gum arabic is a natural resin and forms the colloid layer. The pigment is the coloring agent and is responsible for the density in the image, while the dichromate salt is the sensitizer. Mixing of the gum arabic and dichromate species forms a light-sensitive complex known as gum bichromate (gum dichromate). However, the sensitivity of the compound is not great and thus, printing is best performed with an ultra-violet light source, with the negative in contact with the sensitized paper. The exposure process hardens the gum dichromate, rendering it insoluble in water. Consequently, areas of high density are hardened whereas areas of lower density, where not much exposure to light occurs, are only slightly or not hardened at all, leaving these areas soluble in water. It follows that development occurs simply in water, which as noted will dissolve the unhardened area. Therefore, the pigment residing in this area is lost. In hardened areas the colloid and the pigment dispersed within it are maintained on the paper and form the image.

The paper required for this process is one that should be able to withstand repeated immersions in water. It must also have a fairly rough texture. This property prevents the flaking of areas of image density during development since the hardened insoluble gum is able to adhere better to the paper fibres. Sizing is also useful since it prevents any pigment from entering the paper base. This eliminates any difficulties that may be encountered in removing the pigment and prevents highlight staining.

Materials and Apparatus

- *Chemicals:*

  pigments: any selection of transparent watercolors (AA extremely permanent series), gouache (AA series), tempera colors
  gum arabic, 70 grams
  potassium dichromate, 20 grams
  distilled water, 6 liters
  gelatin, 28 grams
  formaldehdyde (37%), 25 mL
  sodium bisulfite (solution 5%)

- *Papers:*

  4 kinds of high-quality artist's paper or writing paper, such as BFK Rives, Arches, Fabriano, or Saunders
  5 pieces of each kind, approximately 10" × 12"
- exposure template (step wedge, resolution targets from Experiment 1: 4.2.1)
- contact printing frame
- light source: ultra-violet light tubes (350 nm)
- footcandle meter
- pictorial negative, 8" × 10" (long density range)
- reflection/transmission densitometer
- prepared Kodak Curve Plotting Graph Paper
- balance
- graduated cylinder
- light-tight bottles, 100 mL
- assorted glassware
- magnetic stirrer
- blotting paper
- sheet of glass, 11" × 14"
- glass rod (slightly larger than largest print)
- latex gloves
- drying cabinet
- print washer
- 6 Pasteur pipettes
- light microscope

Procedure

1. Select your paper choices, and cut the paper to the required sizes so they accommodate the control template. Our experience has shown that preparing one large sheet of paper and cutting it down to the required size gives more consistent results than preparing several small samples. We have found that the best results are obtained by sizing the paper samples with gelatin, which reduces the feathering of the pigment into the paper fibres. The paper can be prepared in the same manner as preparing salted paper prints. Float both sides of the selected paper types on the solution of gelatin and allow to dry in a cabinet (prepare in a well-ventilated area).

   Sizing Solution:

Gelatin	28 grams
Formaldehyde (37%)	25 mL
Distilled water to make	1000 mL

   (CAUTION — formaldehyde)

2. Assemble all glassware and necessary equipment in a manner that makes for convenient and efficient work.

3. Select watercolor pigments that are traditionally used for watercolor prints. The choice is varied, but as a starting guide choose a dark pigment such as a carbon black.

4. Ready gum solution and sensitizer solution in the following manner:

   Gum Solution:

Distilled water to make	200 mL
Gum arabic	70 grams

   Sensitizer:

Distilled water (warm) to make	88.3 mL
Potassium dichromate	11.7 grams

   Sensitive Coating (Caution — light sensitive):

Gum solution	20 mL
Pigment, your choice	(tube: 1 - 1.6 grams)
Sensitizer	20 mL

   (Formulas from William Crawford: *Keepers of Light.*)

5. There is no exact formula for the sensitizing solution; the modification of the recommended starting solution is just a point from which you can obtain the effect that you desire. So, begin by mixing the selected pigment with the gum arabic solution; once mixed, this stock solution can then be stored until needed again. The choice of pigment is endless, so experiment just for the fun of it!

6. Coating the paper with the sensitive coating solution can take place in an area that is

protected from light sources of high ultra-violet radiation. Normal incandescent light will be fine. Begin by mixing enough of the gum and sensitizer solutions to coat a single sheet of paper.

7. Tape the corners of the selected paper type onto the sheet of glass. Begin by brushing the sensitizer solution in long, even, light strokes along the length of the paper. Continue lightly brushing until the solution evenly covers the paper surface. Next, with the dry soft-bristle brush, lightly stroke the surface in one direction and then the other to ensure a smooth coating. Another technique for preparing the paper stock is instead of dipping the brush into the sensitizing solution, pour the solution onto the paper surface, where you quickly and evenly distribute the small pool of sensitizer over the paper surface. Dry the paper in a drying cabinet in total darkness.

8. In a contact printing frame, expose the prepared paper to a light source that is high in ultra-violet radiation (**use appropriate eye protection**). Measure the appropriate densitometric data for future reference and sensitometric evaluation.

9. After exposure, develop the gum print in a tray of water at 21°C for approximately five minutes. Begin by sliding the print face up into the tray of water. Once the print is covered with water, carefully turn the print over so it is face down. Allow it to develop for the rest of the five minutes. Every five minutes or so, transfer the print into a tray of fresh water until it is fully developed. Full development, depending on exposure, can take anywhere from 20 to 30 minutes. Once it looks good and there is no evidence of pigment coming off the print, remove it from the water bath.

10. When the development of the print is completed and modified to your satisfaction, the image can be cleared using a 5% solution of potassium metabisulfite or sodium bisulfite.

11. Place in a drying rack and allow to dry slowly.

12. Read the samples with the densitometer, and prepare the characteristic curves for the various paper types and pigment choices. Read the resolution targets using the light microscope.

13. Using the data prepared from the template samples, read the pictorial negative and select the pigment/paper choice. Determine the correct negative exposure with the above combination and repeat using the above procedures (see Chapter 4).

Analysis

Make a visual analysis of the template samples and pictorial samples under different angles of light; specifically observe areas where there is a dark and light color. What accounts for the apparent difference in the emulsion thickness of the highlight versus the shadow areas?

Questions

1. What makes this process so popular with students who wish to print historical processes?
2. What features of the gum dichromate process are similar to other historical processes?
3. In which step(s) of this process is it possible to manipulate the gum print?

5.2.6 Experiment 6: Silver Gelatin (POP) Prints

Purpose

To produce images using a commercially prepared printing-out paper and make comparisons using sensitometry with the other printing-out processes.

Introduction

It was not until the 1880s and early 1890s that the market for photographic papers markedly increased. Several factors were responsible for the expanding market. Technical advances in coating photographic papers and a greater interest by the amateur photographer contributed towards the evolution of print materials.

With the introduction of prepared sensitized silver gelatin prints in the early 1870s, the albumen process really began to lose its position as the premier printing-out paper. The new printing-out papers made of collodion or of silver chloride and silver bromide in gelatin were much more sensitive to light than the silver chloride albumen papers.

With the interest and tremendous growth in amateur photography during the 1880s and 1890s, as well as the skill necessary to produce good albumen prints, professionals and amateurs alike changed to the new printing papers.

Printing-out papers are not much different than developing-out papers in their general structure. Silver gelatin printing-out papers are considered "contact speed" printing papers due to the sensitivity of the paper. The printing of a printing-out paper can take from several minutes to more than an hour depending on the light source and paper type combination. There is no chemical development; the image can be toned and then fixed or just fixed. The silver particles of a printing-out paper are very much smaller and different in shape than developing-out papers. The size and shape of the image silver of printing-out papers are responsible for their warm image tones.

Unfortunately, the manufacture of printing-out papers in North America was ended in 1988. Fortunately, a printing-out paper is still available through the Chicago Albumen Works Company. The paper is a chloride-based paper manufactured in France.

Materials and Apparatus

- *Chemicals:*

  sodium thiosulfate (pentahydrate), 250 grams
  sodium sulfite, 20 grams
  distilled water, 2 liters
  gold chloride, 10 grams
  ammonium thiocyanate, 10 grams
  Kodak Hypo Clearing Agent

- *Paper:*

  Kodak Studio Proof Paper (if available) or "Chicago Albumen Works Gelatin Chloride POP Paper" (French)
- exposure template, resolution targets from Experiment 1: (4.2.1)
- light source: high output in ultra-violet radiation
- footcandle or lux meter
- contact printing frame, 11" × 14"
- negative of your choice (suitable for POP papers), 8" × 10"
- reflection densitometer
- prepared Kodak Curve Plotting Graph Paper
- balance
- various sizes of beakers
- graduated cylinder
- thermometer
- 3 glass trays
- light-tight bottles
- tongs
- timer
- ultra-violet protective goggles
- print washer
- squeegee

Procedure

1. Cut the printing-out paper you have chosen into strips that match the size of the template.
2. Gather glassware and containers suitable for storing and mixing chemicals.
3. Prepare the fixing agent according to the following formula:

ANSI Non-Hardening Fixer:

Sodium thiosulfate	250 grams
Sodium sulfite	20 grams
Distilled water to make	1 liter
20°C (68°F)	

4. In a room with subdued tungsten illumination, fill the bottom of the two glass trays with the fixing agent. The trays must be able to accommodate the dimensions of the exposed prints.

5. Set up the ultra-violet light source or equivalent in a darkened room (use **protective eyewear**). Set the timer on the light source for an initial exposure of 20 minutes.

6. Measure and record all data that is pertinent to the printing of the selected paper. This information will be useful for future reference.

7. In a darkened room using a contact printing frame, expose the samples using the template. The exposure is judged in the same manner as for other printing-out materials, i.e., salted paper and albumen processes.

8. Silver gelatin printing-out papers do not necessarily have to be fixed. If the choice is to not fix the samples, then they must be stored in a light-sealable enclosure. To stablize the print, fix in ANSI fixer for 10 minutes (two baths of fixer for 5 minutes each), rinse in water for 1 minute, bathe in Kodak Hypo Clearing Agent for 2 minutes and wash for 20 minutes in a print washer.

9. If you wish to gold-tone the samples, prepare the following Kodak T-53 Gold Toning Formula:

   T-53 Gold Toning Solution:

   Solution A

Ammonium thiocyanate	10 grams
Distilled water	500 mL

   Solution B

Gold chloride	1 gram
Distilled water	500 mL

   Working Solution

Stock A	15 mL
Stock B	15 mL
Distilled water	500 mL

   (Mix just prior to using.)

   Half fill the glass tray with the working solution. Before toning, rinse for 10 minutes, changing the rinse bath with distilled water every 1 1/2 minutes and apply constant gentle agitation. Quickly slide the exposed print face down into the toning solution and tone for 10 minutes. Rinse for two minutes in distilled water. Complete the processing sequence as stated in step 8 above.

10. Lightly squeegee the back of the print and allow to air dry on a suitable drying screen.

11. Take visual and tricolor density readings of the template grey scales and plot the visual readings. Read the resolution targets using a light microscope.

12. Analyse the characteristic curves of the prepared samples and select the pictorical negatives that best suit this process. Expose and process the pictorial negative following the above procedures.

Analysis

Compare the characteristic curves of the toned samples with the untoned samples. Also compare this method of printing-out with the other samples in this chapter. Focus on visual results, the characteristic curves, and resolution values.

Questions

1. What is the purpose of fixing the printing-out paper?
2. Why is it necessary to rinse the paper prior to toning?
3. What effect does toning have on the stability of the print?

5.3 References

Archer, F.S. 1851. On the Use of Collodion in Photography. *Chemist* **2**: 257-258.

Brettell, Richard, et al. 1984. The Calotype as Print Medium. In *Paper and Light: The Calotype in France and Great Britain, 1839-1870*, 47-63. Boston: David Godine.

Coe, Brian, and Mark Haworth-Booth. 1983. *A Guide to Early Photographic Processes*. London: Victoria and Albert Museum and Hurtwood Press.

Crawford, William. 1979. *The Keepers of Light*. Dobbs Ferry, N.Y.: Morgan & Morgan.

Eastman Kodak. 1974. *Kodak Darkroom Dataguide for Black-and-White*. 5th ed. Kodak Publication, no. R-20. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1985. *Conservation of Photographs*. Kodak Publication, no. F-40. Rochester, N.Y.: Eastman Kodak Co.

Eder, Joseph Maria. 1929. *Lichtspausverfahren, die Platinotypie und verschiedene kopierverfahr ohne silbersalze*. Halle: Wilhelm Knapp.

Gill, Arthur T. 1978. Recognition of Photographic Processes. *History of Photography* **2**(1): 34-36.

Krause, Peter. 1989. Color Photography. In *Imaging Processes and Materials: Neblette's Eighth Edition*, ed. by J.M. Sturge, et al. 181-225. New York: Van Nostrand Reinhold.

Pobboravsky, I. 1971. *Study of Iodized Daguerreotype Plates*. Master's thesis, Rochester Institute of Technology.

Reilly, J.M. 1986. *Care and Identification of 19th-Century Photographic Prints*. Kodak Publication, no. G-2S. Rochester, N.Y.: Eastman Kodak Co.

Schaaf, Larry. 1982. Anna Atkins' Cyanotypes: An Experiment in Photographic Publishing. *History of Photography* 6(2): 151-172.

Schramm, H.P., and B. Hering. 1982. *Historische Malmaterialien und Möglichkeiten ihrer Identifizierung*. Dresden: Hochschule für Bildende Kunste.

Spencer, D.A., ed. 1973. *The Focal Dictionary of Photographic Technologies*. London: Focal Press.

Talbot, W.H.F. 1839. Some Account of the Art of Photogenic Drawing. *London and Edinburgh Philosophical Magazine and Journal of Science* **14**: 196-208.

Wächter, Otto. 1982. *Restaurierung und Erhaltung von Büchern, Archivalien und Graphiken*. 3 Aufl. Wien: Bohlau.

Walworth, Vivian K., and Stanley H. Mervis. 1989. Instant Photography and Related Reprographic Process. In *Imaging Processes and Materials: Neblette's Eighth Edition*, ed. by J.M. Sturge, et al. 181-225. New York: Van Nostrand Reinhold.

Ware, M.J. 1986. An Investigation of Platinum and Palladium Printing. *Journal of Photographic Science* 34(5-6): 13-25.

Welling, William.1976. *Collectors' Guide to Nineteenth-century Photographs*. New York: Collier.

5.4 Supplemental Readings

Arnold, H.J.P. 1977. *William Henry Fox Talbot, Pioneer of Photography and Man of Science*. London: Hutchinson Benham.

Atkins, Anna. 1843-1853. *British Algae: Cyanotype Impressions*. 3 vols. Halstead Place, England: privately published.

Brown, George E. 1899. *Ferric and Heliographic Processes*. London: Dawborn & Ward.

Buckland, Gail. 1980. *Fox Talbot and the Invention of Photography*. Boston: David Godine.

Clerc, Louis-Philippe. 1930. *Photography: Theory and Practice*. London: Isaac Pitman & Sons, 381-385.

Coe, Brian. 1977. Making Calotype Paper and Prints. *The Photographic Journal* (London), Nov.-Dec., 281-283.

Crookes, William. 1855. On Wax and Waxing Paper. *Journal of the Photographic Society* **2** (34): 231-232.

Cundall, George. 1844. The Practice of the Calotype Process of Photography. *The London, Edinburgh and Dublin Philosophical Magazine and Journal of Science,* 3rd series, **24** (160): 321-332.

Furlonge, F. Holland. 1856. On the Calotype Process. *Photographic Notes* **1**(1): 5.

Hannaford, Michael. 1859. Iron Printing Process. *Photographic Journal* (London) **6**: 36.

Herschel, Sir John F. W. 1842. On the Action of the Rays of the Solar Spectrum on Vegetable Colours, and on Some New Photographic Processes. *Philosophical Transactions* **132**(1): 181-214.

Jones, Bernard Edward, ed. [1911] 1974. *Cassell's Cyclopedia of Photography.* [London: Cassell]. Reprint. New York: Arno Press, 66-68, 397-398.

Kosar, Jaromir. 1965. *Light-Sensitive Systems: Chemistry and Application of Nonsilver Halide Photographic Processes.* New York: John Wiley & Sons.

Lessard, Elizabeth. 1980. *Cyanotypes: A Modern Use for an Old Technique.* American Association for State and Local History Technical Leaflet, no. 133. Originally published in *History News* **35**(12).

M.D. 1859. Modification of the Waxed Paper Process. *Photographic Journal* (London) **6** (99): 186-188.

Reilly, James. 1980. *The Albumen and Salted Paper Book.* Rochester, New York: Light Impressions Corp.

Snow, V.F., and D.B. Thomas. 1966. The Talbotype Establishment at Reading, 1844-1847. *The Photographic Journal,* no. 106, 58.

Sutton, Thomas. 1855. *The Calotype Process: A Handbook to Photography on Paper.* London: Joseph Cundall.

Sutton, Thomas. 1856. Yellowness in the Lights of Positives. *Photographic Notes* **1**(6): 63.

Talbot, William Henry Fox. 1864. On Photography without the use of Silver. *British Journal of Photography* **11**: 495.

Tennant, John A. 1900. The Blue Print and Its Variations. *The Photo-Miniature,* Jan.

Townsend, F. 1855. On the Quality of Paper Required for Photographic Purposes, More Particularly for the Waxed-Paper Process. *The Liverpool Photographic Journal* **2**(15): 37-38.

Washing glass plate negatives.
1913. Beresford B. Pinkerton.
Contemporary print from copy
negative of original print. National
Archives of Canada/PA-127215.

6 Duplication and Copying

6.1 Introduction

In many cases copying or duplicating a photograph is the best and sometimes the only means of saving or improving the quality of an original picture. Nitrate-base and cellulose diacetate negatives, and any other inherently unstable photographic materials, should be duplicated or copied to preserve image information. Copying and duplicating also provide a means by which rare or fragile images can be protected from frequent handling and potential damage by researchers. Particularly valuable negatives and prints may be duplicated or copied as insurance against loss of the original. Copying for purposes of before-and-after treatment comparisons should be part of the conservation procedure carried out before any treatment program is undertaken. In addition, if chemical restoration techniques such as reduction are to be undertaken the best possible duplicate or copy must be made first.

This chapter is designed to help students learn how to make high quality duplicates and copies. This will help those who become photograph conservators to deal with the variety of image deterioration and collections preservation problems commonly found in archives and museums. In addition, the conservator must know what materials and procedures ensure the maximum stability of the resulting copy photographs and duplicate negatives. This is discussed in this chapter and Chapter 4.

The two terms, copying and duplication, will recur throughout this chapter. The term duplication will be used when a duplicate negative is made from a transparent original. Copying will be used when a copy negative is made of a print or other object photographed by reflected light.

Duplicate negatives are most often produced by one of three different procedures:

1. An interpositive film material may be used to make a positive intermediate. The same or other negative film material may then be used to make the final duplicate negative from the intermediate.

2. A direct duplicating or reversal film may be used to reproduce the original in a single step.

3. A print may be made from the original negative and a copy negative may then be made from the print.

As there are significant disadvantages to method 3 which are to do with the shape of the characteristic curve of printing materials, procedures 1 and 2 will be used exclusively to make duplicate negatives. Making a copy negative from an original print will be discussed in Experiment 8: 6.9.

Regardless of which method is used to produce a duplicate negative, a method is required to judge how accurately the duplicate negative reproduces the tones of the original negative. The method used to do this is to produce a tone reproduction graph; although this is discussed further in Experiment 3: 6.4, a basic introduction is called for here. Instead of plotting log exposure against density for each step of the duplication process, we instead plot the densities of the original negative against those of the duplicate negative. For the time being, we will simply ignore all the steps in the method by which the duplicate negative was made. Figure 6.1 shows such a plot. If the duplication process were ideal, we would expect that the densities in the duplicate negative would be exactly the same as the densities in the original. If plotted against each other, these identical densities would form a perfectly straight line with a slope of 1.00. This is represented in the illustration by the dotted line. By convention the negative part of the slope value is ignored; we will refer to all slopes by their absolute value.

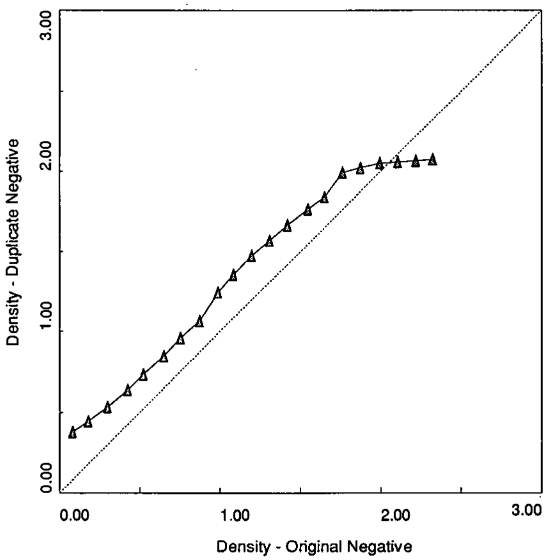


Fig. 6.1: A simple tone reproduction plot.

Since negative materials are for printing and not for direct viewing, we may decide that the absolute densities of the duplicate negative do not have to be identical to the original. Instead it is acceptable for them to be greater or less than the original as long as they are all greater or less by the same amount. Thus if the tone reproduction plot were to show a perfectly straight line with a slope of 1.00, which was higher or lower on the graph than the line illustrated, we may still consider this an accurate duplicate.

Producing a duplicate negative that produces a tone reproduction graph with a straight line and a slope of 1.00 will be the aim of many of the experiments in this chapter. Tone reproduction graphs describe only the large area tones of the subject and say nothing about the sharpness or resolution of the image.

6.2 Experiment 1: Time/Gamma Curves for Negative Duplication

Purpose

To generate sets of time/gamma curves for duplicating materials.

Introduction

The characteristic curve may be used to monitor changes in the response to light of photographic materials caused by variables in processing; it may also be used as a reference to allow placing the densities of the original negative on selected parts of the curve by adjusting exposure time.

Experiment 4: 4.2.4 was designed to demonstrate that different exposure times result in different placement of the original image tones on different regions of the characteristic curve. In pictorial photography, all parts of the characteristic curve may be used to provide an excellent reproduction or interpretation of the original scene. When duplicating historical negatives, however, it is often desirable to use only the straight-line portion of the characteristic curve. Thus precise control over film exposure is very important.

When using a direct duplicating film, it is essential to have the gamma of the film equal to 1.00. When both an interpositive and duplicate negative are being used, the product of their average gradients must equal 1.00. When that is achieved and all of the tones of the original negative are reproduced as a straight line on a tone reproduction graph, then the duplicate negative will have the same density range and contrast as the original negative. Tone reproduction curves are discussed further in Experiment 3: 6.4.

As we have seen in Chapter 4, the slope of the straight-line portion of the characteristic curve is adjusted by changes in development time. The longer the development time, the greater the slope, hence the greater the separation of tones on the interpositive or direct duplicating film.

Chapter 4 contains the definition and formula for calculating gamma. In the following example two points, a and b, have been chosen on the straight-line portion of a characteristic curve. The two points are:

a: Log H = 0.50, Density = 1.00

b: Log H = 1.40, Density = 1.80

Given the formula

$$\text{Gamma} = \frac{\text{Density}_b - \text{Density}_a}{\text{Log H}_b - \text{Log H}_a}$$

and substituting

$$\text{Gamma} = \frac{1.80 - 1.00}{1.40 - 0.50} = \frac{0.80}{0.90} = 0.88$$

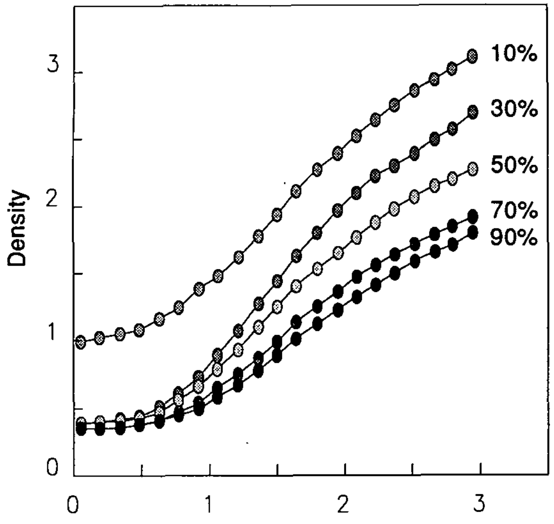


Fig. 6.2: Set of characteristic curves showing the effects of varying development time.

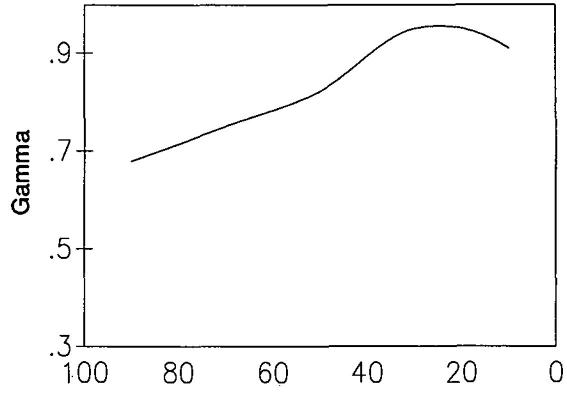


Fig. 6.3: Time/gamma curve produced from data in Figure 6.2.

Thus the gamma in this example is equal to 0.88. (If the two points chosen are not on the straight-line portion of the curve, then the same calculation gives an average gradient instead of gamma.) If the material being measured was a reversal or direct duplicating film, then point b would have a lower density than point a and the gamma would be a negative number. However, by convention the value is written as a positive number.

To determine the appropriate processing times needed to achieve a gamma of 1.00, a series of tests must be carried out. These tests use identical exposures with a step tablet and varying processing times to produce a set of characteristic curves for a given film material. From these curves, a time/gamma curve is generated that may be used later to select the desired processing times to achieve a specific gamma for a film. Time/gamma curves are available from the manufacturer but are only a guide. Due to variations between lots of films and in processing conditions, it is necessary to generate a time/gamma curve using the equipment and film that will actually be used for any duplication work.

This experiment is designed to demonstrate the production of time/gamma curves for two films that will be used a great deal in later experiments in this chapter.

Materials and Apparatus

- Kodak Separation Negative Film, Type 1, #4131
- Kodak Professional Black-and-White Duplicating Film #4168 (replaced by Kodak Professional B/W Duplicating Film SO-339)
- exposure template from Experiment 1: 4.2.1
- contact printing frame
- NuArc point light source
- footcandle meter
- Hope 152 Black-and-White Film Processor
- transmission densitometer
- prepared Kodak Curve Plotting Graph Paper

Part I — Gamma of 1.00: Procedure

1. Turn on the Hope 152 processor and allow it to come up to temperature (85°C). Run clean-up film through and then process control strips at 50% base speed. Read the values on a densitometer. Make any adjustments that may be necessary to the processing solution, such as adding replenisher, until the processor is operating within its control limits.

2. Using the film ISO rating and the illuminance provided by the point light source, determine the approximate exposure time for Kodak Separation Negative Film, Type 1, #4131. Use the ISO (supplied on the film instruction sheet) for tungsten light.

3. Label all film samples. Expose the first 4" × 5" film sample for the recommended time, using the exposure template from Experiment 1: 4.2.1 (incorporating a Kodak photographic step tablet no. 2 and R.I.T. Alphanumeric Resolution Targets). As a recommended starting point for determining the correct exposure, make a number of test exposures, at intensity 3 for 5 seconds, 10 seconds, and 15 seconds.

4. Process the samples in the Hope 152 processor at 50% base speed. When dry, measure and record the visual density of each step of the step tablet. Plot the characteristic curves on the prepared Kodak Curve Plotting Graph Paper. Keeping in mind the results of Experiments 4: 4.2.4 and 5: 4.2.5, examine the density readings and decide if more or less exposure is required, and if more or less development time is necessary. Consider the following guidelines:

   a. If the density range is quite low and there is a long toe region, longer exposure time will be required.

   b. If there is little or no toe region but a larger shoulder region, less exposure is required.

   c. If the density range is very low and gamma is less than 1.0, longer development times or a lower percent of base processing speed is required.

   d. If the density range is quite large and the gamma exceeds 1.0, less development or a greater percent of base developing speed is required.

5. Expose and process more samples if necessary, following the guidelines above. When a gamma of 1.0 ± 0.05 is achieved, with a curve with a long straight-line portion and no more than two or three steps of the toe region showing, then the exposure and development times are correct.

6. Using the prepared Kodak Curve Plotting Graph Paper, draw a complete curve for the final sample, including calculations of the total density range, density range of the straight-line portion of the curve and by extention the log exposure range of the straight-line portion of the curve.

7. The second film to be used for duplicating is Kodak Professional Black-and-White Duplicating Film #4168 (formerly SO-015). The manufacturer's directions for exposing this film should be followed so that the first trial exposure of the material will be 40 seconds with an illuminance of 32.3 metercandles. Using the exposure template, expose three test samples under the NuArc point light source. Expose the other two samples for 30 and 50 seconds. Label all samples.

8. Process the samples in the film processor at 50% base speed. When dry, measure and record all visual densities and draw characteristic curves on the prepared Kodak Curve Plotting Graph Paper. Because #4168 is a direct duplicating film, the curve will appear opposite to that of a normal curve, with D-max at the lowest log exposure. The ideal result will be a gamma of 1.00, with a long straight-line portion. This film has a long toe region. In order to use only the straight-line portion, the maximum density should be 2.0 to 2.5. Minimum usable density (i.e., the lowest portion of the straight line) should be approximately 0.10 above film "base plus fog". With a gamma of 1.00, the density range should equal the log exposure range of the straight-line portion of the curve.

9. Expose and process more samples if necessary, remembering that longer processing increases gamma and that increasing exposure reduces the density of the duplicate negative.

10. Draw a complete curve for the final sample, including calculations of the total density range, the density range of the straight-line portion, and the log exposure range of the straight-line portion of the curve.

Part II — Time/Gamma Curves: Procedure

1. Using the exposure template, expose six 4" x 5" sheets of Separation Negative Film, Type 1, #4131 using the optimum exposure time and intensity as determined in Part I. Label all samples.

2. Process the samples in the Hope 152 processor, varying the percent base speed for each sample. Process one sample at 40, 60, 80, 120, 140, and 160% of the base speed, which gave a gamma of 1.0. For example, if a gamma of 1.0 was achieved at 50% base speed, process one sample at each of the following base speeds: 20%, 30%, 40%, 60%, 70%, and 80%.

3. When the samples are dry, measure and record all visual densities. Plot the characteristic curves and determine the gamma of each sample.

4. Draw a time/gamma curve. The Y axis will be gamma co-ordinates, and the X axis will be percent base speed co-ordinates. The gamma axis should be labelled in 0.2 increments with the marked 0.01 increments in between. The percent base speed co-ordinates should be marked in 10% increments up to 100%.

5. Repeat steps 1 through 4 (Part II) using Kodak Professional Black-and-White Duplicating Film #4168.

Questions

1. Examining the final curves of the film samples, determine the amount of log exposure required to place density No. 21 of the step tablet on the straight-line portion of each characteristic curve.

2. Describe how processing time affects gamma.

3. What other variables affect the gamma during processing?

4. Does the shape of the characteristic curves change with changes in processing?

6.3 Experiment 2: Duplication of Black-and-White Negatives

Purpose

To duplicate a black-and-white negative.

Introduction

The duplication of black-and-white negatives requires that all of the densities on the original negative be reproduced as accurately as possible in the duplicate negative. Although these densities at different stages of the duplication process may vary, the density differences and total density range should remain the same. Many early negatives, especially wet collodion glass plate negatives, have a long density range, often ranging between 1.90 and 2.20, and require a duplicating material that will accommodate this large density range while still producing a straight line on a tone reproduction graph. Most good duplicating films have good resolving characteristics, a short toe region, and a long straight-line portion. When a direct duplicating film is used it must also be capable of being processed to a gamma of 1.00.

When an interpositive and negative are used, the product of the two average gradients must be equal to 1.00.

In this experiment, only the straight-line portion of the characteristic curve of three different films will be used. First, the correct exposure and development times will be established that yield a gamma of 1.00 using a step tablet. Then two densities will be found that represent the minimum and maximum densities of the original, which must be recorded. The selection of these two points is not always straightforward. The simplest rule of thumb is to measure the minimum and maximum densities where detail must be recorded. Thus specular reflections that may represent the maximum density of the original would likely not be selected. For convenience in processing and adjusting exposure, these two values are then located on the step tablet, which will be used for initial tests before the original is used. For example, if the maximum density to be recorded is 1.48, then we would look at the step tablet densities and use step 3, which might have a density of 1.50. If the minimum density to record was 0.40, we would use step 10 with a density of 0.30 as our second aim point. If in locating these points on the step tablet we discover that the tonal range of the original negative does not lie on the straight-line portion of the interpositive characteristic curve, an adjustment to the exposure will have to be made. The density range of the original can be moved onto the straight-line portion by adjusting the exposure. The following formulas may be used to determine an approximate exposure correction.

$$X = Y\,[\,\text{antilog}\,(\Delta D/\tau)\,]$$

where X = required new exposure
Y = initial exposure (sec.) (intensity is constant)
ΔD = change in density required
τ = gamma

Example:
If the data that produced a gamma of 1.0 was 32 seconds at 3.767 mc., and to move step 10 off the toe would require a move of 0.20 density units, the new exposure time would be

ΔD = 0.40 (D-min of original; step 10) minus 0.20 (required shift)
= 0.20

X = 32 [antilog (0.40 - 0.20)/1]
= 50.7 seconds

If the exposure time has to be reduced, the inverse of this formula is

$$X = \frac{Y}{[\text{antilog}\,(\Delta D/\tau)]}$$

Once the corrected exposure has been determined and the film processed correctly, the gamma of the characteristic curve between the two selected steps should be 1.0. When using the interpositive/negative method and making the interpositive, if the slope does not come out to 1.0, it is possible to compensate for this by processing the duplicate negative to a higher gamma. The "**slope product**

rule" states that if the gamma of the interpositive is multiplied by the gamma of the duplicate negative, the product must be 1.0. For example, if the interpositive gamma equals 0.80, the duplicate negative gamma must be increased to 1.25.

$$\tau_p \text{ (positive) } \times \tau_n \text{ (negative) } = \text{unity } (1.0)$$

$$\tau \text{ interpositive } \times \tau \text{ duplicate negative } = 1$$

$$0.80 \times 1.25 = 1$$

Sharpness and granularity is affected to some extent by the length of time the material is developed. If it is necessary to extend the processing time to achieve a gamma of 1.0, the interpositive may show increased granularity and less sharpness. This can sometimes, depending on the sharpness characteristics of the two materials, be compensated for by processing the interpositive at a much higher gamma than 1.0, and processing the duplicate negative at a lower gamma, using the slope product rule. This may help to limit the grain size of the resulting duplicate negative.

This experiment describes the steps of duplicating a negative using both a direct duplicating film and an interpositive/negative process. Evaluation of the results will be made in the next experiment.

Materials and Apparatus

- Kodak Separation Negative Film, Type 1, #4131
- Kodak Professional Black-and-White Duplicating Film #4168
- exposure template from Experiment 1: 4.2.1
- original pictorial negative for duplicating
- transmission densitometer
- prepared Kodak Curve Plotting Graph Paper
- contact printing frame
- Hope 152 Black-and-White Film Processor

Procedure

1. Choose a negative to be duplicated that has a total density range greater than 1.50. Determine minimum and maximum end point densities that must retain detail on the original negative. Locate and make note of the two steps on the exposure template step tablet that correspond to these two points on the negative. When a point does not correspond to a point on the template exactly, use the next step with just less density for the minimum point and with just greater density for the higher density point.

2. Using the exposure time and percent base processing speed determined in Experiment 1: 6.2, expose a sheet of Kodak Separation Negative Film, Type 1, #4131 in contact with the exposure template. Label this and all samples to follow. Process it in the Hope 152 film processor. When it is dry, read the visual

densities of the interpositive and plot the characteristic curve on prepared graph paper. If gamma is not 1.00 ± 0.05, repeat this procedure, adjusting the development time. Locate the chosen D-min and D-max points of the original on the interpositive. The D-max of the original should be located very close to 0.50 on the interpositive. If they both lie on the straight-line portion of the curve, then an interpositive can be made from the original. If one of the points is located on either the toe or the shoulder region, apply one of the following formulas to determine a new trial exposure:

a. toe region $X = Y\,[\text{antilog}\,(\Delta D/\tau)\,]$

b. shoulder region $X = \dfrac{Y}{[\text{antilog}\,(\Delta D/\tau)\,]}$

3. Expose another piece of film using the new exposure time and process it in the Hope 152 processor at the already established percent base speed. Read the densities and plot the characteristic curve. If a gamma of 0.95 to 1.05 has not been achieved, adjust the processor and repeat the process until the gamma falls in that range.

4. Produce an interpositive of the original negative, using the final exposure time and development time.

5. Calibrate a piece of graph paper using the ΔD values determined from the interpositive step tablet. The interpositive now becomes the exposure template for determining the correct exposure and development times for producing the duplicate negative.

6. Expose a piece of film to the interpositive exposure template and process according to times determined for the production of the interpositive. Read the densities and plot the characteristic curve on newly calibrated graph paper. Again, a gamma of 1.00 ± 0.05 is required, and the D-max and D-min points of the original negative should lie on the straight-line portion of the curve. The D-min point should be somewhere around 0.50. If the gamma is low, lower the base speed; if it is too high (above 1.0), increase the percent base speed of the Hope 152 film processor. If the density range of the original lies on either the toe or the shoulder region of the curve, adjust the exposure using the formulas outlined in step 2 of this procedure. It may be helpful to place the plot generated using the interpositive template over a curve generated with the original template. The Kodak Curve Plotting Graph Paper facilitates this by being semi-transparent.

7. Make final adjustments to the development time and exposure time, if necessary, and produce a final duplicate negative of the interpositive exposure template.

8. Produce a duplicate negative from the interpositive of the original negative, using the exposure time and percent base speed determined in step 7 above.
9. Determine the resolution of the interpositive and duplicate negative.
10. Make a test exposure on Kodak Professional Black-and-White Duplicating Film #4168, using the exposure time and the percent base speed of the Hope 152 processor, as determined in Experiment 1: 6.2, to result in a gamma of 1.00. Label this and all subsequent samples. If the gamma is not 1.00 ± 0.05, either raise or lower the percent base speed until 1.00 is achieved.
11. Using the same original 4" × 5" pictorial negative, and the same D-min and D-max points as used with the #4131 film, find and indicate the two points on the characteristic curve of the #4168 film. If the points lie on the straight-line portion of the curve, the duplicate negative can be made. If not, since #4168 is a reversal film and more exposure causes less density, use the reciprocal of the formulas listed above to determine the proper exposure.
12. Once exposure adjustments have been made and the characteristic curve drawn, expose and process the duplicate negative.
13. Determine the resolution of the film (#4168).

Analysis

Write a brief report on the procedures used, results obtained, and problems encountered in using these two films to duplicate a pictorial negative.

Questions

1. What is the importance of placing the tones of the original negative on the straight-line portion of the characteristic curves of the interpositive and duplicate negative materials?
2. Which duplicate negative appears sharpest and why?

6.4 Experiment 3: Methods for Comparing Duplicate Negative Quality

Purpose

To demonstrate two methods for evaluating the quality of duplicate negatives.

Introduction

To ensure that the duplicate negatives reproduce the tones of the originals as exactly as possible, two methods will be used for evaluation:

1. A tone reproduction diagram demonstrates graphically the reproduction of tones of the

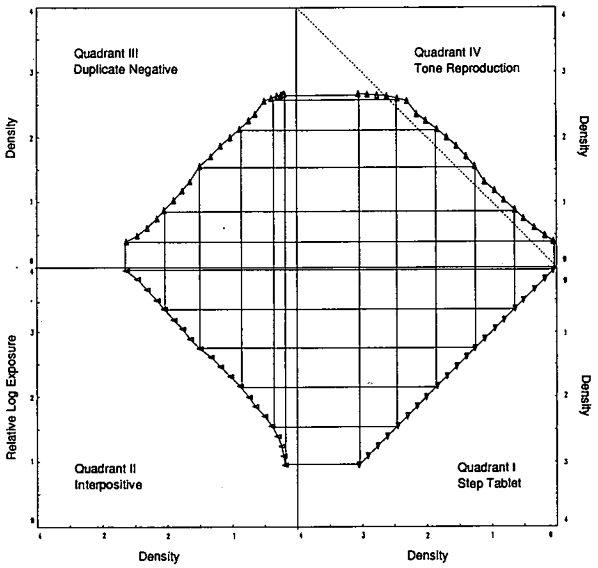


Fig. 6.4: Four-quadrant tone reproduction graph.

original negative. In the case of the interpositive/negative process this is done by plotting the densities of the duplicate and comparing them to the densities of the interpositive and original negative on a four-quadrant graph. The fourth quadrant is then used to compare the tone reproduction of the duplicate negative with that of the original negative. In this way the contribution of each phase of the process can be seen.

2. A photographic print can be made to compare the results of the duplication procedure. This is done by determining the optimum exposure for the original negative on a selected paper. The printing paper is chosen sensitometrically. So that the density range of a negative can be accommodated on a particular printing paper, the negative's density range should equal the log exposure range of the paper. Some variation is acceptable and sometimes preferred. A print of the duplicate negative is made to ensure that selected density areas match with the same points on the print from the original. The two prints are then compared visually and densitometrically for any variations in detail, tone, or contrast.

Materials and Apparatus

- exposure template from Experiment 1: 4.2.1
- interpositives from Experiment 2: 6.3
- duplicate negatives from Experiment 2: 6.3
- Ilford Ilfobrom Galerie Paper
- Ilford Galerie processing chemicals
- transmission densitometer
- reflection densitometer
- diffusion enlarger
- contact printing frame
- prepared Kodak Curve Plotting Graph Paper

Part I — Tone Reproduction Diagram: Procedure

1. Assemble all of the density readings required for the tone reproduction diagram. These include the densities of the original exposure template containing the Kodak photographic step tablet no. 2, the interpositive, and the final duplicate negative.

2. Divide a piece of graph paper into four equal quadrants. The paper should be at least 8" × 11".

The quadrants represent the following:

a. Quadrant I (lower right) — original no. 2 step tablet

b. Quadrant II (lower left) — interpositive step tablet

c. Quadrant III (upper left) — duplicate negative

d. Quadrant IV (upper right) — actual tone reproduction

a. *Quadrant I*: Both the horizontal and vertical axes of the quadrant represent density values. On the horizontal axis, the densities increase from right to left. There must be enough units along the axis to accommodate all of the densities found on the Kodak photographic step tablet no. 2. The densities on the vertical axis increase in descending order. The increments on both axes are the same. Plot the densities of the step tablet in Quadrant I. This should be a straight line running diagonally across the quadrant at a 45° angle.

b. *Quadrant II*: The vertical axis of this quadrant represents the relative log exposure and the horizontal axis the densities. Draw lines parallel to the horizontal axis from all 21 steps of the original step tablet across Quadrant I and Quadrant II. These lines represent the log exposure co-ordinates for each of the 21 steps of the interpositive. The density values increase from right to left on the horizontal axis. Plot the density values of the interpositive in Quadrant II, where the density values intersect with the densities of the original template. This represents the characteristic curve of the interpositive.

c. *Quadrant III*: The horizontal axis represents the relative log exposure and the vertical axis the densities increasing in ascending order.

Lines parallel to the vertical axis are drawn from each of the 21 points of the interpositive in Quadrant II, through Quadrant II and through Quadrant III. These lines represent the relative log exposure co-ordinates for the characteristic curve of the duplicate negative. Plot the densities of the duplicate negative where these lines intersect the negative's densities in Quadrant III.

d. *Quadrant IV*: Draw lines from all 21 points of the curve in Quadrant III parallel to the horizontal axis. Extend the lines through Quadrant IV. Draw lines parallel to the vertical axis from each of the 21 steps of the original step tablet in Quadrant I through Quadrant IV. The points at which the perpendicular lines meet are then used to form the tone reproduction curve. If all tones are correctly duplicated, the line should be straight and should be the mirror image of the line in Quadrant I. This, however, is very unlikely to happen in practice. Draw a line diagonally across Quadrant IV at a 45° angle to the axis. This line should be drawn by plotting the densities from Quadrant I against themselves in Quadrant IV. This line is to be used for comparative purposes. The closer the curve is to the line in angle and length of the straight-line portion, the more accurate the tone reproduction will be.

3. Two points representing the minimum and maximum points where detail must be maintained were chosen on the original negative. These points were selected at the beginning of the duplication procedure and from these the density range was determined. A primary objective when duplicating historical negatives is to be sure these points fall on the straight-line portion of the tone reproduction curve. The density values of the selected D-min and D-max points with detail are matched with specific steps on the original step tablet having the same density value. Mark these steps on the line in Quadrant I and on the curves in Quadrants II, III, and IV. Draw lines connecting these points. This gives a graphic demonstration of the location of the original negative's density range in relation to the tone reproduction of the step tablet.

Part II — Comparison Prints: Procedure

1. Select an appropriate printing paper for the original and the duplicate negative from Experiment 2: 6.3. The effective density range of the negative when printing with a diffusion enlarger should equal the useful log exposure range of the paper. (Determining the log exposure range is discussed in Experiment 7: 6.8.) For this experiment, use the following chart, which indicates the appropriate paper grade for negative density ranges and the corresponding log exposure ranges.

Kodak Paper Contrast Number	Paper Log Exposure Range	Suitable Negative Density Ranges Diffusion Enlarger	Condenser Enlarger
1	1.15 to 1.40	1.15 to 1.40	0.86 to 1.05
2	0.95 to 1.14	0.95 to 1.14	0.71 to 0.85
3	0.80 to 0.94	0.80 to 0.94	0.60 to 0.70
4	0.65 to 0.79	0.65 to 0.79	0.49 to 0.59
5	0.50 to 0.64	0.50 to 0.64	0.38 to 0.48

Fig. 6.5: Appropriate paper grades for negative density ranges.

2. Print the original step tablet on the chosen paper. Make sure that the chosen D-min and D-max points with detail from the original negative lie on or as near to the D-min useful and D-max useful points of the printing paper characteristic curve as possible.

3. When the correct exposure has been determined, print the original negative. Process the print using established procedures described earlier in this study guide. Take density readings at the chosen D-min with detail and D-max with detail areas. Calculate the density range between these points and the total density range.

4. Print the duplicate negative matching the densities of the D-min and D-max points of the print from the original negative with the same points on the print from the duplicate negative. Correct the exposure time of the print if necessary.

5. Pick 10 points on the print from the original negative covering the full range of tones, from D-min to D-max. Take density readings at these points. At the same 10 points on the print from the duplicate negative, take density readings.

Analysis

Compare the two sets of readings, in Part II, step 5 above, for consistency of tone reproduction. Report on your findings.

Questions

1. Quadrant IV of the tone reproduction diagram shows the accuracy of the duplication method. How are defects in the reproduction curve apparent in the comparison prints?

2. How effective are the two methods of comparison?

6.5 Experiment 4: Duplication of 35-mm Negatives

Purpose

To demonstrate five methods for duplicating 35-mm and other small-format negatives.

Introduction

A historical photographic collection may be expected to contain not only large format negatives (4" × 5" and larger) but many small format negatives as well. These negatives can range in size from the 1 5/8" diameter of the circular Gray detective camera (ca. 1885) to the 35-mm and 2 1/4" square negatives in use since the 1930s.

Five common methods for duplicating 35-mm negatives will be demonstrated in this section:

1. Contact print the original negative onto film to produce first an interpositive and then a duplicate. This method maintains the 35-mm format.

2. Enlarge the original to produce a 4" × 5" interpositive. Contact print this interpositive onto the appropriate material to produce a 4" × 5" duplicate negative.

3. Contact print the original onto Kodak rapid processing copy film SO-185 or Kodak Professional Black-and-White Duplicating Film # 4168 to produce a direct duplicate negative.

4. Enlarge the original onto Kodak Professional Black-and-White Duplicating Film #4168 to produce a 4" × 5" direct duplicate negative.

5. Using a slide duplicator, reproduce the 35-mm negative through the camera onto Kodak rapid processing copy film SO-185.

When dealing with small-format negatives, standard contact printing of interpositives and duplicate negatives may not be adequate. Due to their small size, and the fact that image quality is lost at every step of the duplication process, enlarging the negative to produce a large-format interpositive and duplicate negative is preferred.

This technique cannot be used where the original's 35-mm format must be maintained. This can be judged more clearly at the printing stage. A print from a duplicate negative that has been enlarged at the interpositive stage and then contact printed to produce the duplicate negative provides a far superior print to one that was printed from a duplicate produced by contact printing the original 35-mm negative. To preserve details and to duplicate as nearly as possible the original tonal range, the original negative should be enlarged onto a fine-grain, medium-contrast film.

The use of direct duplicating film has certain advantages, in that it eliminates the interpositive stage thus decreasing the time and resources required to produce a duplicate negative. This also reduces the number of generations and therefore some loss in sharpness involved in the two-stage interpositive/duplicate negative process. However, it may be more difficult to exactly duplicate the tonal range of the original, without the intermediate adjustments offered by the interpositive stage.

This experiment will investigate the five procedures listed above for duplicating small-format negatives. The results will be examined to determine which procedure (contact printing or enlargement, interpositive or direct duplication) and which film type (standard negative film or direct duplicating film) provides the best tone reproduction and resolution.

Materials and Apparatus

- Kodak Separation Negative Film, Type 1, #4131
- 4" x 5" Kodak Professional Black-and-White Duplicating Film #4168,
- Kodak Aero Leader #5986
- 35-mm negative for duplicating, average contrast and tonal range
- contact printing frame
- 4" x 5" diffusion enlarger with flat field apochromatic lens
- R.I.T. Alphanumeric Resolution Targets
- Kodak photographic step tablet no. 2
- reflection densitometer
- Kenro Spectra 1000 Slide Duplicator
- Hope 152 Black-and-White Film Processor
- sheet film holder, 4" x 5"
- prepared Kodak Curve Plotting Graph Paper
- Ilford Ilfobrom Galerie enlarging paper
- Ilford Galerie processing chemicals
- Kodak rapid processing copy film SO-185

Method I — Duplication by Contact: Procedure

1. Make an exposure template that is equal in size to two frames of 35-mm film, using a Kodak step tablet no. 2, three R.I.T. Alphanumeric Resolution Targets (one negative and two positive), and Kodak Aero Leader #5986. Cut a 35-mm wide strip of aero leader and mark where two standard size frames would be if it were regular 35-mm film. Cut a 1/4" strip off one side of a Kodak step tablet no. 2 so that all 21 steps are included. Cut

this strip into three equal pieces, each piece containing seven steps. In the center of one of the frames, place the three pieces side by side. Cut out the center of the frame to the same size as the step tablet pieces. Using thin strips of tape on the non-emulsion side, secure the pieces in the aero leader. In the center of the second frame, place the resolution targets using the same procedure as with the step tablet. The three resolution targets together should measure approximately 1.5 cm × 5 cm. Install the 1-mm aperture on the transmission densitometer and take visual density readings of the 21 steps. Calibrate a sheet of Kodak Curve Plotting Graph Paper using the density differences between steps.

2. Bring the Hope 152 film processor up to temperature, and run through clean-up film and process control strips before exposing and developing samples. Use the exposure time and development base speed established in Experiment 1: 6.2 for Kodak Separation Negative Film, Type 1, #4131. Expose and process a test sample of #4131 with the new exposure template. Label this and all subsequent samples. With the 1-mm aperture installed in the transmission densitometer, measure and plot the densities of the step tablet. Use the calibrated Kodak Curve Plotting Graph Paper. It is essential to achieve a gamma of 1.00 ± 0.05.

3. If the gamma of the sample is 1.00 ± 0.05, determine the density range of the original 35-mm negative and choose the minimum and maximum density points where detail must be retained. Locate these points on the steps of the step tablet. If the points are on the straight-line portion of the curve plotted in step 2, the original negative can be contact printed to produce the interpositive. If the points lie off the straight-line portion, adjust the exposure time accordingly. (Use the formulas outlined in Experiment 2: 6.3.) When the correct exposure has been determined, produce the interpositive of the original negative.

4. Once the interpositive has been produced, use the interpositive step tablet as the exposure template for the determination of the correct exposure and development times for the duplicate negative. Again, use Kodak Separation Negative Film, Type 1, #4131 for the duplicate negative. Calibrate a second piece of graph paper using the interpositive step tablet. If the selected D-min and D-max with detail of the original negative lie on the straight-line portion of the duplicate negative step tablet, the duplicate of the original can be made from the interpositive of the original.

5. Plot the characteristic curve of the duplicate negative and determine the resolution from the resolution targets.

Method II — Duplication by Enlargement: Procedure

1. This method involves enlarging the original negative onto 4" × 5" format film. This is accomplished by placing the 4" × 5" interpositive film in a film holder, setting it on the enlarger base, and enlarging the exposure template, which has been placed in the 35-mm negative easel in the enlarger. First, however, move the enlarger head up the column and focus the image of the exposure template onto a sheet of film in a "focusing film holder," to be used only for precision focusing before exposure of the actual sheet of interpositive film. Focusing should be done using the maximum aperture of the lens and all other work done with the lens closed down two stops. When the column height has been adjusted to fit the image on the 4" × 5" format, use a footcandle meter to determine the illuminance at the film plane. Determine the correct exposure time based on the log exposure used in Method I above. Use the following formula:

$$\text{Exposure} = \text{Intensity} \times \text{Time}$$

$$\therefore \text{Time (sec.)} = \frac{\text{Exposure (metercandle-sec.)}}{\text{Intensity (metercandle)}}$$

Example:

old exposure = 60 metercandles-sec.
new intensity = 15 metercandles
new time = ??

$$\text{new time} = \frac{60 \text{ mcs}}{15 \text{ mc}}$$

new exposure = 4 seconds

Determine the illuminance with the exposure template removed from the negative carrier, using a footcandle meter. Return the exposure template to the enlarger and make a test exposure. Label this and all subsequent samples. Process it in the Hope 152 processor at the base speed determined in Experiment 1: 6.2. Adjust the development for a gamma of 1.0, if necessary, and adjust the exposure so that the density range of the original falls on the straight-line portion of the curve. Once the characteristic curve has been drawn, an approximate exposure adjustment may be made using the following formulas:

$$X = Y\,[\text{antilog}\,(\Delta D/\tau)]$$

and to decrease exposure

$$X = \frac{Y}{[\text{antilog}\,(\Delta D/\tau)\,]}$$

2. Once the correct exposure and processing are determined, replace the step tablet with the resolution targets and make an interpositive.

3. Replace the exposure template with the original negative, focus carefully on the focusing film holder, and make the interpositive.

4. Measure the densities of the interpositive step tablet and draw the characteristic curve. Calibrate a piece of Kodak Curve Plotting Graph Paper using the interpositive density values. The interpositive becomes the exposure template for the duplicate negative stage.

5. The 4" × 5" interpositive is exposed in a contact printing frame with another 4" × 5" sheet of Kodak Separation Negative Film, Type 1, #4131. Develop according to the percent base speed determined in Method II.

6. Make adjustments to development and exposure times if necessary.

7. Replace the interpositive step tablet with the 4" × 5" interpositive of the resolution targets and then of the original. Expose and process, using times determined above.

8. Read the resolution targets for both the interpositive and duplicate negative.

Method III — Duplication by Contact with Kodak Professional Black-and-White Duplicating Film #4168: Procedure

1. Using the exposure time and development time (% base speed) determined in Experiment 2: 6.3, contact print the exposure template in a contact printing frame onto a piece of Kodak Professional Black-and-White Duplicating Film #4168. Make the necessary adjustments to exposure time and development so that a gamma of 1.0 is achieved and the density range of the original is accommodated on the straight-line portion of the curve. Use the procedure outlined in Experiment 2: 6.3 to determine the change in exposure time. Label this and all subsequent samples. Read the densities and plot the curve on a piece of calibrated graph paper.

2. Replace the exposure template with the original negative, expose, and process it.

3. Read the resolution targets of the duplicate exposure template.

Method IV — Duplication by Enlargement onto Kodak Professional Black-and-White Duplicating Film #4168: Procedure

1. Place the exposure template in the negative carrier of the diffusion enlarger. Place the focusing film holder on the base of the enlarger and focus the image (the step tablet) onto the appropriate area and at the proper magnification. Remove the step tablet from the negative carrier, and take an incident light reading at the duplicate film exposure plane. Take the exposure calculated for contact printing (Method III above) and use the formula given in Method II to determine the correct exposure time.

   Place the exposure template back into the enlarger and expose a 4" × 5" sheet of Kodak Professional Black-and-White Duplicating Film #4168. Use the development procedure determined in Method III. Read the densities and draw the characteristic curve for the enlarged duplicate. If the gamma is equal to 1.0 and the density range of the original lies on the straight-line portion, proceed to duplicate the original.

2. Place the original negative in the enlarger negative carrier and focus the image at the duplicate film exposure plane. Expose a 4" × 5" sheet of #4168 film and process it as indicated in step 1 above.

3. Determine the resolution of the duplicate exposure template from the R.I.T. Alphanumeric Resolution Targets.

Method V — Duplication by 1:1 Reproduction onto Kodak rapid processing copy film SO-185: Procedure

1. The Kenro Spectra 1000 slide duplicator will be used to reproduce a small-format negative of the same size as the original using duplicating film. Place the exposure template in a slide mount and place the mount in the 35-mm holder above the light source. Load the 35-mm camera body with Kodak rapid processing copy film SO-185 (35-mm format). To maintain 1:1 reproduction, make sure to carefully adjust the size according to the frame indicators in the viewfinder. Stop down the lens aperture to approximately f/8 for greater depth of field. Using the light meter in the camera, expose several frames. Bracket one stop over and one stop under the recommended exposure. In the dark, cut off the exposed film from the roll and place this film in a light tight paper safe. Reload the camera. Label the sample (and all subsequent samples) and process the film in the Hope 152 processor. Prepare the leading edge of the roll film (the "Klunker" prepares the leading edge of the roll of film) to ensure that it does not get caught in the rollers of the film transport mechanism. Measure the densities and plot the curve on a piece of calibrated graph paper. Make any adjustments to exposure and development times that may be necessary.

2. Replace the step tablet with the resolution targets and expose and process according to times determined above.

3. Replace the resolution targets with the original negative and expose and process the resulting duplicate according to times and procedures determined above.

4. Read the resolution targets on the resulting duplicate negative.

Analysis

1. Draw and label tone reproduction diagrams (as outlined in Experiment 3: 6.4) for the final duplicate negative for each method of duplication examined in this section.

2. Draw a chart of the resolution characteristics determined for each of the reproduction methods. Determine the percentage loss of resolution for each method.

3. Make the best possible print from the original negative and from all of the final duplicate negatives from each of the five methods examined here. Follow the procedure outlined in Experiment 3: 6.4 for comparing the positive reflection prints.

Questions

1. Which duplication method yields the best results? Why?

2. Which method lends itself to high-volume production of duplicate negatives?

3. What other methods may be suitable for duplicating 35-mm negatives?

4. Flare is an important factor whenever optical systems are used in place of contact printing. Based on the tone reproduction plots, what was the effect of flare?

6.6 Experiment 5: Copy Setup

Purpose

To demonstrate the equipment and use of a grey scale for copying photographic reflection materials and to show the methods and effect of using cross-polarized light.

Introduction

A high-precision copy camera is the best device to copy two-dimensional pieces. However, where that is not available, the 4" × 5" monorail view camera can serve adequately for copying black-and-white reflection prints, daguerreotypes, ambrotypes, tintypes, and non-silver reflection materials.

The ability to expose and process to very specific requirements single sheets of film necessitates exacting methods. The use of a large copy negative reduces the loss of detail by limiting the degree of enlargement necessary to produce a copy print of the original at, in some cases, a 1:1 ratio. The bellows of the view camera allows a 1:1 reproduction of small objects and photographs, eliminating the need for enlarging the copy negative.

Specialized flat field, high-resolution, and chromatic aberration-corrected lenses are available for precision copy work for 4" × 5" format or larger. The adjustment features of the camera body permit perspective correction for large originals that cannot be placed parallel to the axis of the film. Placement of the subject on the ground glass may be adjusted by horizontal or vertical controls, rising and falling front and back planes, and front and rear tilts and swings.

The work to be copied must be illuminated by a controllable light source. Several steps can be taken to eliminate unwanted reflections around the copy area as well as from those emanating from the material being copied.

1. The copy area should be covered with a dark grey or mat black material or paint.

2. The light source should consist of at least two lights, placed on either side of the copyboard and at a 45° angle from the surface of the material to be copied.

3. The lights must be placed at a distance that provides even illumination over the copyboard area. Two lights may provide sufficient coverage for small originals, but four lights or more should be used for larger photographs.

4. Polarized illumination is preferred in certain situations: to illuminate subjects with specular reflections; to provide a high degree of color saturation of an original subject that is to be copied for reproduction purposes; and to reduce surface glare from mat surfaces on subjects.

The measurement of the intensity of the light falling upon the copyboard can be measured with two different instruments. The footcandle meter is used to measure the illuminance at the copyboard. The meter probe can be moved across the illuminated area to determine the evenness of illumination.

Similarly, a light meter of the type normally used to determine camera exposures may be used depending on the model in one of two ways:

1. It measures the intensity of illumination being reflected by the subject; this method is generally used in pictorial photography to determine the scene log luminance range.

2. It measures the intensity of illumination falling on the subject, using an incident light meter. This is often the preferred type of meter to use in evaluating the subject

illumination when copying flat artwork, evenly lit three-dimensional subjects, or photographic reflection methods.

The incident light meter can also be used to evaluate the evenness of subject illumination. The meter probe faces the light source while sitting on the exposure plane and is moved across the illuminated area. Any fluctuations of the meter indicates uneven illumination, which calls for an adjustment of the copying lights.

When copying photographic reflection prints, as when duplicating negatives, a measurement is required of the copy film's ability to reproduce tones under set exposure and development conditions. To do this a "reflection" exposure modulator or grey scale, which includes 20 steps each reflecting a different amount of light, is used. Similarly reflection resolution targets may also be used. This allows us to draw the characteristic curve of the copy film and to locate the density range of the original photograph on the straight-line portion of the curve. Any required changes to exposure and development time can thus be calculated. As with negative duplication, copy films must have the ability to be developed to a variety of gammas and should have a long straight-line portion to their characteristic curves.

Materials and Apparatus

- Kodak Q-13 gray scale
- R.I.T. Alphanumeric Resolution Test Target 2" × 2" positive reflection print
- 18% reflectance gray card
- double-sided tape
- Kodak Commercial Film #4127, 4" × 5" sheets (alternative film: Kodak Professional Copy Film #4125)
- Sinar View Camera, 4" × 5"
- film holders, 4" × 5"
- 2 Kodak Pola-Light, Model 2 (with Pola-Screen)
- footcandle meter or incident light meter
- 10 times magnifier
- polarizing filter for camera
- flat black easel with non-reflective surfaces
- coin with highly reflective surface
- Kodak Curve Plotting Graph Paper
- reflection densitometer
- transmission densitometer
- Hope 152 Black-and-White Film Processor

Procedure

1. Measure the densities of every step of the Q-13 gray scale. Use these values to calibrate a piece of Kodak Curve Plotting Graph Paper. Make copies of the calibrated graph paper.

2. Mount the Q-13 gray scale and the R.I.T. Alphanumeric Resolution Test Target onto an 8" × 10" 18% reflectance gray card, also supplied by Kodak. Use double-sided tape to hold them in place. This will serve as an exposure target.

3. Set up an easel or copy stand that is painted flat black with no reflective surfaces, or that can be covered with black velvet. Place the exposure target on the easel or copyboard. Attach it with glue, if necessary.

4. Move the 4" x 5" camera into place. Open the aperture and shutter and make certain that the exposure target is parallel to the ground glass focusing screen of the camera. To do this, mount the camera so that the lens axis is in line and perpendicular with the center of the copyboard. As an aid to doing this, standard size rectangles 4" x 5", 5" x 7", 8" x 10", etc., may be drawn on the copyboard and centered in the viewfinder or camera back. The outer border of these rectangles must be carefully aligned with the grid of the ground glass in the view camera. When this has been done, place a flat mirror on the center of the copyboard. Make any fine adjustments necessary until the image of the camera lens is seen through the camera in the center of the mirror.

5. Set up two studio lights (flood lights) on either side of the camera, pointing at the exposure target, and placed at a 45° angle from the surface of the exposure target.

6. Turn on the lights and, using a footcandle meter or incident light meter, determine the evenness of illumination across the entire surface of the exposure target. If the surface illumination is uneven, move the lights around until it is even. The 45° angle should be retained, however, so that the potential for surface glare is minimized.

7. Using a 10 times lupe (magnifier) on the ground glass, focus the camera on the exposure target. Determine the exposure using the incident light meter. Close the shutter and set the appropriate shutter speed and aperture setting. The aperture setting should be f/8 or f/11 for reasonable depth of field.

8. Load Kodak Commercial Film #4127 into film holders and then load the camera. Expose three sheets of film at the recommended shutter speed and aperture.

9. Process the film in the film processor. Process one sample at 30% base speed, one at 50% base speed, and one at 70% base speed.

10. Measure the visual densities of the three grey scales. Plot the curves on the calibrated graph paper from step 1 above. As with the negative duplication process, the characteristic curve should have a gamma of 1.0 with a long straight-line portion and slight shoulder and toe region. Make the necessary adjustments to exposure time and development to accomplish this. Use the following formula for exposure adjustment increase:

$$X = Y\ [\text{antilog}\ (\Delta D/\tau)]$$

Use the inverse of this formula if the exposure must be reduced.

11. Using the corrected times, produce another sample. Measure densities and draw the characteristic curve. Calculate the total density range and log exposure range.

12. Polarize the light, using polarizing filters that are placed in front of the camera lens and in front of the two studio lights. Follow this procedure to set the filters for maximum polarization:

    a. Place a highly reflective coin in the center of the subject to be photographed. Place the camera polarizing filter over the lens and turn off one of the lights.

    b. Turn the polarizing screen in front of the single light to the horizontal position. This axis should be indicated on the screen by an arrow and the word "axis."

    c. Look through the camera lens and rotate the camera filter until the reflections on the coin are at a minimum. If the screen on the light is horizontal, the camera polarizing filter should be rotated 90° from that axis or in the vertical position.

    d. Turn out the first light and turn on the second. Without disturbing the camera filter, while looking through the camera lens, rotate the screen on the second light until all reflections are minimized.

    e. When this final adjustment has been made, the light is fully polarized, resulting in minimum surface reflection.

    f. The use of polarizing light requires exposure adjustments. Take an incident light meter reading at the subject, with the screens over the lights. Add the number of stops indicated by the camera lens polarizing filter factor to compensate for this lens filter. Use this as a starting point to determine the correct exposure.

13. With both lights on, re-focus the camera using the 10 times lupe on the ground glass. Determine the exposure as outlined above.

14. Make several test exposures: one as determined by the light meter and filter factor; one at one stop under; and one at one stop over the suggested setting. Label all samples.

15. Process the samples in the Hope 152 film processor at the percent base speed established in step 10 of this experiment. This should result in a gamma very close to 1.00.

16. Measure the densities of the grey scales on the resulting samples and plot their characteristic curves. Adjust the exposure time according to the procedure in step 10 of this experiment and re-expose, if necessary.

17. Draw the characteristic curves of the final copy negatives with and without polarized light onto one sheet of graph paper and compare them.

18. Make the best possible print from each of the negatives using standard printing procedures.

Questions

1. What is shown by the density differences between the polarized and non-polarized film samples?

2. How does polarized illumination affect the reproduction of the subject?

3. How does the polarized light mechanism work?

4. The characteristic curves generated in this experiment are different from those generated using the same film while contact printing in other experiments. How are they different and why?

6.7 Experiment 6: Evaluation of Condenser and Diffusion Enlargers

Purpose

To show the differences between condenser and diffusion enlargers and to calculate the Callier Coefficient.

Introduction

An enlarger is a projection printing device used to increase or reduce the size of a photographic image that has been recorded on a transparent base. For a basic description of these devices, see Chapter 2. The kind of light source and optical arrangement used to illuminate the negative affects printing contrast. Diffusion enlargers illuminate the film being projected with diffuse light — that is, light that strikes the surface of the film from almost every direction. This is accomplished by placing a diffusing glass or plastic between the light source and the film as close as possible to the film. These systems are relatively inefficient in their use of light. Diffusion enlargers also tend to reduce the effect of minor scratches and dust marks and in general provide even illumination across the surface of the negative. Many of these systems now employ fluorescent light sources known as "cold light" illuminators. These sources produce little heat, keeping the negative relatively cool, so it is less likely to curl out of focus during exposure.

In condenser enlargers, the light from the light source is directed rather than diffused. This is accomplished by condenser lenses that sit between the film and the light source. The rays are focused by the condensers onto the back element of the enlarging lens. This type of illumination is also referred to as specular illumination. The use of a condenser enlarger increases the visibility of scratches and dust marks on the film in the projected image. Condenser enlargers also increase printing contrast to levels higher than that produced by contact printing or projection printing with diffusion enlargers.

This effect, also known as the Callier effect, occurs because the silver in the denser areas of a negative will not only absorb light but scatter it. Some of the light that is scattered is scattered away from the lens and cannot contribute to the exposure of the print material. This effect is most pronounced in the parts of the film image where the density is greater than 1.00. It is also more noticeable for the higher speed, coarse-grained emulsions. Callier defined the factor Q as the ratio of spectral density to diffuse density. Unfortunately this factor is dependent on many factors including density, the gamma, and the type of material.

Materials and Apparatus

- 4" × 5" copy negative from Experiment 5: 6.6
- Ilford Ilfobrom Galerie paper, 8" × 10"
- reflection densitometer
- footcandle meter
- Ilford Galerie processing chemicals
- Omega ProLab 4" × 5" condenser enlarger
- Omega Super Chromega D Dichroic II diffusion enlarger
- Kodak Indicator Stop Bath
- Kodak Dektol developer
- printing easel, 4" × 5"
- prepared Kodak Curve Plotting Graph Paper

Procedure

1. Place the 4" × 5" copy negative from Experiment 5: 6.6 into the negative carrier of the condenser enlarger. Turn on the enlarger and enlarge the image to an 8" × 10" format, using the 150-mm lens. Focus the enlarger with the lens at its maximum aperture and adjust the printing easel to the correct size.
2. Stop down the enlarger lens to f/8. Remove the negative from the carrier and return the carrier to the enlarger head. Using the footcandle meter, measure the light intensity from the enlarger at the paper exposure plane.
3. Make the best possible print from the negative and process it according to the procedure that follows. The print should have two or three steps of absolute D-min at one end of the grey scale and two or three steps of absolute D-max at the other end.

Developer — Dektol 1:2:	2 minutes
Stop bath — Kodak Indicator Stop Bath:	30 seconds
Fixer — Ilford Ilfospeed paper fix:	30 seconds
Wash:	5 minutes
Washaid — Ilford Galerie Washaid:	10 minutes
Wash:	5 minutes
Air dry	

4. Take visual density readings using a reflection densitometer and draw the characteristic curve on calibrated graph paper.

5. Place the copy negative from Experiment 5: 6.6 into the negative carrier of the diffusion enlarger. Turn on the enlarger and match the enlarged image to the image size of the print produced in the condenser enlarger. Both prints must be identical in size. The same 150-mm lens should be used on both enlargers.

6. Remove the negative from the carrier, set the lens aperture at f/8 and determine the illuminance at the paper plane, using the footcandle meter. Make the required adjustments to the exposure time so that the log exposure is the same. For example, where A and B are the illuminance and exposure time respectively:

$$A \times B = C \times D$$

A = illuminance (footcandles)
B = exposure time (seconds)
C = new illumination (footcandles)
D = new exposure time (seconds)

A = 2.5 fc.; B = 5 sec.; C = 1.8 fc.; D = ?

$$D = \frac{A \times B}{C} = \frac{2.5\text{ fc.} \times 5\text{ sec.}}{1.8\text{ fc.}} = 6.94\text{ sec.}$$

7. Match the density of step 10 of the grey scale produced on the condenser enlarger with that of step 10 of the grey scale produced on the diffusion enlarger. Use the procedure outlined in step 3 above.

8. Take visual density readings and plot the curve on the same piece of graph paper as that used for the condenser enlarger print readings. If step 10 of both prints is not of equal density, don't plot the curve. Repeat the printing procedures, adjusting exposure until they match.

9. Determine the ratio of the densities of the condenser and diffusion prints.

10. Read and record the R.I.T. Alphanumeric Resolution Test Targets.

Questions

1. How would you compare the effects of the condenser versus diffusion enlargers quantitatively?

2. Which enlarging system is best suited for printing copy negatives? Why?

6.8 Experiment 7: Determination of the Density Range, Log Exposure Range, and the Contrast and Speed of Photographic Papers

Purpose

To demonstrate the calculation of log exposure range, contrast, and speed of photographic papers.

Introduction

As discussed in Chapter 2, photographic papers are divided into two categories: printing-out papers and developing-out papers. Silver halide printing-out papers, such as those used to make albumen prints, collodio-chloride prints, and those commonly called "studio-proofing papers," have a low sensitivity to light and produce images without the need for chemical development. The metallic silver image of these prints is formed strictly by exposure to light, followed by desensitizing or fixing in a thiosulfate acid fixing solution. These papers have an extremely long tonal scale, range in hue from red to purple to brown, and are generally lower in contrast than modern papers.

Developing-out papers will be used in this experiment. Silver gelatin developing-out papers have several sub-groups, based on the emulsion type, speed, contrast, and log exposure range of the various papers. Gelatin and silver halide are the primary components of these papers. Two main halogens, chloride and bromide, are used separately or in combination in different paper emulsions, each having different sensitometric characteristics. Silver chloride papers have a low sensitivity to light (they are "slow") and traditionally produced images that were lower in contrast, with a warm tone and a finer filamentary silver structure. These papers are sometimes used for contact printing negatives and for making proof prints. Silver bromide papers are very sensitive to light (they are "fast") and usually produce prints that are neutral-black to blue-black in image tone and with a larger filamentary silver structure. These papers are most often used for enlargement printing. Chlorobromide papers produce a warmer toned image than the bromide papers. They are slower than bromide papers and are used for both contact printing and enlarging. All developing-out papers, once exposed, are processed in an alkaline developer solution, which makes the latent image visible by reducing the exposed silver halide grains to metallic silver.

Most photographic papers are designed to have a specific degree of contrast. Contrast grades of various papers are available from grades 0 or 1 to 5. The higher the number, the higher the contrast, and the more the log exposure range decreases. Grade 2 is often considered to be the medium or average contrast on which correctly processed pictorial negatives should be printed.

The type of photographic paper emulsion, the exposure, the developer used, and subsequent processing procedures all contribute to how a negative "prints." Using standardized exposure and processing procedures, we can determine the basic characteristics of a print material such as density range, log exposure range, contrast, and speed. Once this is done, this information may be used to select the correct paper grade and exposure to best print a copy or duplicate negative. The relationship between negative and print is outlined in ANSI/ASC PH2.2-1984, *Black-and-White Continuous-Tone Papers — Determination Of ISO Speed And Range For Printing:*

> "Practical experience and special studies have shown . . . that satisfactory prints are usually obtained if the paper chosen for printing each negative has a log exposure range approximately equal to the effective density range of the negative. The relationship between the two variables is not critical and need not be exact. Assuming normal pictorial subjects and normal scene lighting, this relationship should hold true."

A method of measuring the speed of photographic papers is outlined in this same ANSI Standard. Paper speed calculations are important for determining printing exposure times.

Unfortunately, we do not have the same control of paper contrast that is available for controlling the contrast of negative materials. Photographic papers generally reach a maximum contrast after a brief development time. This is usually just after the maximum achievable density has been developed. Further processing has the effect of uniformly darkening all the values in the print and does not significantly increase contrast.

The contrast of photographic papers is not based on the slope of the characteristic curve directly but rather on the log exposure range,which produces the useful density range of the paper. The log exposure range is also referred to as the scale index or exposure scale of the paper.

The calculation of log exposure range is described in Chapter 4.

Materials and Apparatus

- Kodak photographic step tablet no. 3
- Kodak Aero Leader #5986
- Ilford Ilfobrom Galerie Paper, Grades 1.1K, 2.1K, and 3.1K, 8" × 10" sheets
- contact printing frame
- Ilford Galerie processing chemicals
- diffusion enlarger with 80-mm lens
- reflection densitometer
- transmission densitometer
- Kodak Curve Plotting Graph Paper

Part I — Sample Preparation: Procedure

1. Read the transmission densities of the Kodak photographic step tablet no. 3 and calibrate the Kodak Curve Plotting Graph Paper using the procedure outlined in Chapter 4.

2. Move the diffusion enlarger head up to the top of the column, focus the lens, and open the lens to f/4.5.

3. Using the Kodak photographic step tablet no. 3 and a contact frame, make test exposures on strips of Ilford Ilfobrom Galerie

paper grade 2.1K. Label these and all subsequent samples. An acceptable exposure is one in which the first 2 to 3 steps of D-min are pure white and the first 2 to 3 steps of D-max are black or absolute D-max.

4. Process the test strips using the Ilford Ilfobrom Galerie system, or as outlined in ANSI Standard PH4.29-1986.

5. Once the correct exposure time has been determined, make an exposure template, using the Kodak photographic step tablet no. 3 and Kodak Aero Leader.

6. Using the exposure time determined above, expose the step tablet five times onto one 8" × 10" sheet of grade 2.1K Galerie paper. Process the paper according to the procedure used above.

7. Repeat these procedures using sheets of Ilford Ilfobrom Galerie grades 1.1K and 3.1K.

8. Take visual density readings, using the reflection densitometer. Record the readings for all five strips on each piece of paper. Average the readings for each of the 21 steps of the step tablet. The result should be one set of 21 readings for each of the paper types.

9. Using the graph paper calibrated in step 1 above, plot (one per page) the characteristic curves for each of the paper grades.

Part II — Sensitometric Analysis: Procedure

1. Take the absolute minimum density value of each of the characteristic curves of the paper samples. This point is the "base plus fog". Add 0.04 to the "base plus fog" value. This is the useful D-min value. Locate and mark this point on each of the curves.

2. Take the absolute maximum density value of each of the characteristic curves. Multiply this value by 0.90. This is the D-max useful point. Locate and mark this point on each curve. These points are referred to as the useful D-max.

3. Find the log exposures on each characteristic curve that produced the points found in steps 1 and 2. Subtract the log exposure to produce the useful D-min points from the log exposure to produce the useful D-max. The resultant value is the log exposure range or scale index of the paper.

4. The actual log exposure range can also be determined by taking a second piece of graph paper and laying the density scale or Y axis along the log exposure axis of the characteristic curves. Line up the origin, 0.0, on the log H, which produced the useful D-min, and read the value of the axis where the log H that produced the useful D-max is. That value is the scale index.

Standards for the determination of paper contrast have not been adapted the way they have for camera films. Paper grades from different manufacturers are likely to represent different printing contrasts. It is always best to measure the contrast and speed of all photographic materials using the equipment and processing conditions that they will actually be used in. This is particularly important for photographic papers. Most manufacturers (and ANSI) do provide charts indicating the appropriate paper grade for negative density ranges and the corresponding log exposure ranges.

Question

1. Take the already determined log exposure range of the three paper samples and compare them to the paper log exposure range numbers from the Kodak chart in Figure 6.5. Examine also the ANSI chart on page 14, appendix D, of ANSI/ASC PH2.2-1984, *Black-and-White Continuous-Tone Papers — Determination Of ISO Speed And Range For Printing.*

Paper Speed

As stated in Section 4.6 of ANSI/ASC PH2.2-1984, "the speed of a photographic material is a numerical expression of its sensitivity to light for conditions of exposure and development that conform to normal use." The calculation of the speed of photographic papers begins with a determination of the speed point on the characteristic curve. This is located 0.60 density units above the "base plus fog".

1. Determine the log exposure value of the speed point for each of the paper grades. Take the antilog of the value to determine meter-candle-seconds and insert these values into the formula

   $$S = \frac{10^3}{H_M}$$

   S = ISO paper speed

   $10^3 = 1000$

   H_M is the exposure, in lux seconds, required to produce a density of 0.60 above "base plus fog" density.

2. Knowing the speed of photographic papers gives you some idea of the sensitivity of the paper, as well as allowing you to calculate the change in exposure time when changing from one printing paper to another or from one grade to another. All you need to know is the speed of both papers.

$$t_2 = \frac{t_1 \times S_1}{S_2}$$

t_1 = old time
t_2 = new time
S_1 = old paper speed
S_2 = new paper speed

3. Produce a chart comparing the three paper grades according to density range, log exposure range, contrast, and speed.

Questions

1. Why is 0.90 of D-max used as the maximum useful density?
2. What relationship is there between the way paper speed is determined and the way film speed is determined?
3. What does the contrast grade of the paper indicate?
4. Why are different grades of paper manufactured?
5. Describe the possible appearances of a print when the density range of the negative and the log H range of the paper are not matched.

6.9 Experiment 8: Copying Black-and-White Photographs of Various Density Ranges

Purpose

To demonstrate methods for copying historical and contemporary silver prints with different density ranges.

Introduction

Often it is desirable to copy historical photographs on paper. Unfortunately, unlike duplicating transparent materials, producing an accurate copy print is often difficult. The most difficult objects to copy are ones that have a full tonal range. This is because even if the toe and shoulder of the copy film can be avoided, lens flare and the shape of the characteristic curve of the final printing paper will work together to compress the highlight and shadow tones of the original. If the original does not have a wide tonal range, then a more successful copy print can usually be made. In that case, the conservator has the choice of actually expanding the tones of the original by using the entire exposure range of the printing paper or of staying off either the shoulder or toe of the printing paper in order to produce a more accurate copy of the tonal range of the original.

In this experiment three originals of varying contrast will be copied using the second approach of attempting to reproduce exactly the tones of the original. In this case a D-min and D-max aim density are chosen on the original. A copy negative is then made of the original with the correct gamma so that the two end aim densities (D-min and D-max) will print with the same density on a copy print.

A good copy film should have the following characteristics:

1. It has a long straight-line portion.
2. It can be processed to a gamma that is roughly the reciprocal of that of the photographic paper on which the copy is to be printed.
3. It has good resolving characteristics.
4. It is panchromatic, so that it can be used with color filters to minimize the reproduction of stains.

Materials and Apparatus

- Kodak Commercial Film #4127, 4" x 5" (alternative film: Kodak Professional Copy Film #4125)
- Ilford Ilfobrom Galerie Paper, 8" x 10"
- Ilford Galerie processing chemicals
- Hope 152 Black-and-White Film Processor
- Sinar View Camera, 4" x 5"
- 4" x 5" Omega Super Chromega D Dichroic II enlarger
- reflection densitometer
- transmission densitometer
- Kodak Curve Plotting Graph Paper
- 3 historical photographs: 1 low contrast, 1 medium contrast, 1 high contrast

Procedure

1. Begin with the medium contrast (average density range) original. Determine the density range of the original print by taking density readings at two points. One point should be a high density area that is just barely lighter than the darkest part of the print. The second point should be a minimum density area that is just barely darker than the lightest area of the print. Mark the placement of these two points and of the original photograph on a Mylar sleeve. Punch holes in the sleeve at these points and place the photograph in the sleeve. Take density readings at these two points. Subtract the selected useful D-min density reading from the useful D-max density reading. We will refer to the result as the useful density range.

2. Select a photographic printing paper that has a log exposure range as close as possible to the density range of the original photograph.

3. Locate the two selected densities of the original print on the characteristic curve of the selected grade of printing paper. Mark off these two points and find the log exposure range between them. Divide the log exposure range by the useful density range of the original. This value is the aim gamma the internegative must be processed to.

4. In this case Kodak Commercial Film #4127 will be used. Load several sheets into film holders. Use the exposure target from Experiment 5: 6.6, made up of a Kodak Q-13 gray scale and a R.I.T. Alphanumeric Resolution Test Target, both adhered to an 18% gray reflectance card. Set this on an easel or lay it flat against a flat black background. Line up the 4" × 5" camera so that the exposure target fills the frame and is parallel to the film plane. Focus carefully on the ground glass. Use two lights, one on either side of the camera at a 45° angle from the picture frame. Using an incident light meter, examine the evenness of illumination. Determine the exposure time with the aperture at f/8 or f/11.

5. Load the film into the camera. Expose it at the recommended aperture and shutter speed. Expose two more sheets of film, one at one stop over and one at one stop under the recommended exposure setting. Label the samples.

6. Before processing the film in the Hope 152 film processor, run clean-up film and process control strips through the machine to be sure the chemicals and temperature are under control. Process the film samples at 50% base speed. Plot the characteristic curves of the three samples and determine the gamma. Determine where on the curve the density range of the original sits. If it lies on the shoulder region, this means that the highlights of the copy print will be compressed and will have little detail. Adjust the exposure time using the following formula:

   $$X \text{ (new exposure time)} = \frac{Y}{[\text{antilog } (\Delta D/\tau)]}$$

   If the densities lie in the toe region, use the inverse of this formula. Examine the gamma of the three samples. If it is higher than the aim gamma by 0.05, determined in step 3, increase the percent base speed of the Hope 152 processor. If it is lower by 0.05, reduce the percent base speed accordingly.

   Adjust the gamma until it is equal to the aim gamma.

7. Repeat step 6, using corrected exposure time and percent base speed.

8. When the correct exposure time and processing speed have been determined, replace the exposure target with the original. Photograph the original using the exact exposure and processing times determined in step 7.

9. Use the diffusion enlarger to print the copy negatives. Place the negative of the original in the 4" × 5" negative holder in the enlarger. Focus on the printing easel. Make sure the size of the copy print exactly matches the size of the original print. Lock the enlarger head

on the column. Remove the negative from the carrier and insert the negative of the target and take an incident light reading of the middle density step at the paper exposure plane. Determine the speed of the paper, as outlined in Experiment 7: 6.8. Use the speed of the paper to determine the correct exposure, using the formula:

$$t = \frac{k}{I_{av} \times S}$$

t = exposure time
k = constant
= 1000 (when I_{av} is in metercandles)
= 92 (when I_{av} is in footcandles)
I_{av} = average illuminance on the printing plane
S = ISO paper speed

Because of variations in processing procedures, the age of the light-sensitive material, and variations in enlarger light sources, the results of this equation are only a starting point for determining the correct exposure.

10. Print the copy negative of the exposure target. Process the prints according to the Ilford Ilfobrom Galerie procedure. Adjust the exposure until the density of the original grey scale that is closest to the original's useful D-min is printed with exactly the same density on the print.
11. Once the correct exposure has been determined, make a final print from the copy negative.
12. Repeat steps 1 through 11, using the low contrast (short density range) and then the high contrast (long density range) originals.
13. Take density readings on the copy prints at the same spots used on the originals to determine the density ranges. Determine the density ranges of the copy prints and compare them to the originals.
14. Make tone reproduction diagrams for each of the three photographs copied.

Questions

1. What procedures would you follow to reproduce the low and medium contrast pictures with improved contrast?
2. After looking at the tone reproduction diagram for the high contrast original, at what stages in the reproduction process is tonal accuracy lost?
3. What density ranges can be accommodated using contemporary photographic materials? What density ranges can be accommodated accurately?
4. What techniques can you suggest to give a more linear response to the photographic copying process when a high contrast original must be copied?

6.10 Experiment 9: Copying Daguerreotypes, Ambrotypes, and Tintypes

Purpose

To demonstrate methods for copying daguerreotypes, ambrotypes, and tintypes.

Introduction

The image seen on the daguerreotype plate is produced by a scattering of light rather than by reflected light. When viewed at different angles, the image will be quite sharp and vibrant, or will disappear completely. To control the light-scattering effects of the daguerreotype plate, you must use polarized light when copying these images. Bare daguerreotype plates are extremely delicate, and you must take care not to touch the image surface. (The decision to remove an original sealed glass cover and brass mat from a daguerreotype must be made in consultation with the responsible curator. The paper used to seal the "sandwich" may contain important historical identifying information.)

The ambrotype is made from a slightly underdeveloped or reduced wet collodion glass plate negative that is backed, after processing, with a piece of black cloth or paper or painted with black lacquer on the back, causing the collodion negative to appear as a positive image. The collodion image may have been lacquered on the recto, to protect it. This glass plate is usually protected by a brass mat and cover glass and then enclosed in a case like those used for daguerreotypes. The double layer of glass causes unwanted reflections that create flare over the image and in the camera lens system. The use of polarized light during copying prevents this flare.

A tintype is made from a piece of iron that is first painted with black or brown lacquer and then coated with a wet collodion emulsion. After exposure and processing, the tintype image itself may be lacquered to prevent damage. Tintypes tend to be low-contrast images with muddied highlights. The tintype plate is soft and thus quite sensitive to pressure and can easily become dented or bent through poor handling and storage. These images are sometimes found in decorative cases like those used to display daguerreotypes and ambrotypes. More often, however, they are found loose, in albums, or in paper wrappers.

The use of polarized light greatly reduces the reflections that are emphasized in the copy negative. A film like Kodak Professional Copy Film #4125, with a high gamma in the upper portion of the characteristic curve, may be used to enhance the detail in the highlight areas of the copy print.

Materials and Apparatus

- daguerreotype, in a case, with little tarnishing; ambrotype, in a case, with black background intact; tintype, with emulsion intact
- Sinar View Camera, 4" × 5"
- 4" × 5" film holders
- Kodak Professional Copy Film #4125
- Hope 152 Black-and-White Film Processor
- Ilford Ilfobrom Galerie Paper, 8" × 10"
- Ilford Galerie processing chemicals
- diffusion enlarger
- transmission densitometer
- reflection densitometer
- exposure template from Experiment 5: 6.6
- Kodak Curve Plotting Graph Paper

Procedure

1. Obtain a daguerreotype, an ambrotype, and a tintype. Be sure they are all in good condition, which will make it easier to determine the density range. Handle them with care.

2. Hold the Kodak Q-13 gray scale from the exposure template up against the daguerreotype, ambrotype, and tintype. Make a close visual examination and try to match the image tones of each original with specific tones of the grey scale. Determine a D-min and D-max point where detail must be retained for each of the originals and mark down the corresponding tones on the grey scale.

3. Take density readings from the Q-13 gray scale at the D-min and D-max points for each of the originals. These points represent the density ranges of the originals.

4. Set up the exposure template on a copyboard or easel with two lights set at 45° angles from the exposure plane. Set up the camera so that the template fills the frame and is parallel to and focused on the ground glass.

5. Take an incident light meter reading and check the evenness of illumination.

6. Load the Kodak Professional Copy Film #4125 into film holders and expose one at the indicated exposure, one at one stop over, and one at one stop under the indicated exposure. Label these and all subsequent samples.

7. Process the three film samples in the Hope 152 film processor at 50% base speed.

8. Read the visual densities of the grey scales of the three samples and draw the characteristic curves on a piece of calibrated graph paper. Draw all three curves on the same sheet of graph paper.

9. The paper to be used for the copy print is Ilford Ilfobrom Galerie, grade 2.1K. From Experiment 5: 6.6, we know the density range, log exposure range, and speed of this paper. More importantly however, we may locate

the selected D-min and D-max useful points of the original on the paper characteristic curve and determine the log exposure range between them. Divide the log H range by the density range between the original points to get the gamma required for the internegative.

10. Adjust the exposure and development times of the copy film so that the chosen daguerreotype D-min and D-max points lie on the straight-line portion of the curve and the gamma is equal to the value obtained in step 9.

11. When the correct exposure time and percent base speed have been determined, replace the exposure template with the daguerreotype. Adjust the polarizing filter and screens, and calculate the filter factor. Expose a negative and process it at the specified percent base speed.

12. Place the copy negative in the diffusion enlarger and focus the image on the easel on the base board so that the size exactly matches the size of the original. If the original size is too small or if a larger copy is required, adjust the enlarger head accordingly. Lock the position on the column, remove the negative, and replace it with the exposure template. Using a footcandle meter, determine the illuminance given by a mid-density on the step wedge. Using the following formula, determine an initial printing time for the copy negative.

$$t = \frac{k}{I_{av} \times S}$$

t = exposure time
= ?
k = constant
= 1000 (if I_{av} is in metercandles)
= 92 (if I_{av} is in footcandles)
I_{av} = average illuminance on the printing plane
S = ISO paper speed

Example:

Given an I_{av} of 0.65 footcandles and an $S = 25$:

$$t = \frac{92}{0.65 \times 25}$$
$$= 5.66 \text{ sec.}$$

13. Print, process, and plot the characteristic curve of the grey scale. Adjust the exposure time so that the selected D-min useful point on the step wedge prints with the same density as on that step of the original grey scale. Use the following formulas to adjust exposure:

    If more exposure is required:

    $$X = Y\,[\text{antilog}\,(\Delta D/\tau)]$$

    If less exposure is required:

    $$X = \frac{Y}{[\text{antilog}\,(\Delta D/\tau)]}$$

When the corrected exposure is determined, replace the copy negative of the exposure template with the copy negative of the original. Make another print adjusting the exposure, if necessary, to make the best possible print.

14. Process the prints using the Ilford Ilfobrom Galerie processing procedure.

15. Take density readings on the final copy print at the same points used on the original print to determine the density range. Determine the density range of the copy print and compare it to the original print.

16. Prepare a tone reproduction diagram for each of the three original photographs being copied.

Questions

1. In what circumstances must one visually determine the D-min and D-max points of the originals?

2. If a print with greater contrast is desired, what would be the best technique to achieve it?

6.11 Experiment 10: Copying Cyanotypes and Other Non-Silver Photographs

Purpose

To demonstrate methods that can be used when copying cyanotypes and other non-silver reflection materials.

Introduction

Prior to performing remedial conservation treatments on cyanotypes and other non-silver photographic materials, faithful copies must be made as insurance against the possible loss of valuable historical images, and as documentation of the before-treatment condition of these images. In addition, curators may wish to make copies available for research use, rather than the fragile originals.

Cyanotypes, blue monochrome images on thin paper, usually found unmounted, were often used as an easy and inexpensive proofing method for negatives. For this reason, in many cases, they provide a record of the unretouched, uncropped negative image. These photographs can be low in contrast and often may be enhanced through the use of high-contrast films or by increasing the gamma of medium-contrast copy films. When making copy negatives, Kodak Wratten gelatin filters should be used to absorb the hue of the original image. These filters increase the image contrast by filtering out light reflected from the image-forming substance that would otherwise contribute to the exposure of the copy film. In other words, when an image is neutral in color, all wavelengths of light are absorbed to a greater or lesser degree depending on the density of any given part of the image. When an image is a definite color such as blue, the blue light striking the image is not absorbed but is instead reflected. This light is then recorded on the copy negative with the result that the contrast of the image is reduced.

This experiment demonstrates the copying of non-silver, monochromatic, and brightly colored prints. Colors can range from the cyan of cyanotypes to the colored pigments used in gum bichromate prints. Our goal here is to allow differences in the amount of color within the original to be represented on the copy film as distinct, well-separated grey tones. To make this possible, we use color separation filters for copying. The filter to be used is the complementary color of the original print (the color directly opposite on the color wheel), in the case of monochromatic images. The filter absorbs all wavelengths of light except the block of wavelengths that give it its color. The original print absorbs in varying degrees all wavelengths of light except those that give it its own color, which it reflects.

Materials and Apparatus

- Kodak Professional Copy Film #4125
- Sinar View Camera, 4" × 5"
- film holders, 4" × 5"
- studio copy lights
- polarizing filter and screens
- incident light meter
- three original non-silver photographs:
  one cyanotype
  one gum bichromate
  one woodburytype
- reflection densitometer
- transmission densitometer
- diffusion enlarger
- Ilford Ilfobrom Galerie papers, 8" × 10"
- Ilford Galerie processing chemicals
- Kodak Viewing filters
- Kodak Wratten gelatin filters (thin band separation filters)
- color wheel
- prepared Kodak Curve Plotting Graph Paper
- exposure target from Experiment 5: 6.6
- Hope 152 Black-and-White Film Processor

Procedure

1. Obtain one cyanotype, one gum bichromate print, and one woodburytype. Choose prints that are reasonably well-exposed and in good condition. Choose two points on each of the prints, one representing D-min where detail must be maintained, and the second representing D-max where detail must be

maintained. Using the Mylar sleeve method of marking (see Experiment 8: 6.9), note the position of the original and placement of these two areas on each image. Take visual density readings and determine the visual useful density range of each.

2. Determine the correct color separation filter required for each print. With a set of Kodak Viewing filters and a color wheel, determine exactly what filter or combination of filters is required to obtain the complementary colors of each of the prints. For example, the complementary color (the color directly opposite) cyan (for the cyanotype) is red. Therefore, select a red filter (Kodak Wratten gelatin filter No. 25). Hold the filter up to the original and see if the image appears to turn black. If so, the filtration is correct. For colors such as brown, a combination of filters will be required (in this case, violet and blue).

3. Set up the copy stand or easel against a black background. Place the exposure target on the easel in such a way that the prints may be butted up against the grey scale. Set up the camera. For each print, fill the frame with the grey scale of exposure target and the print and focus sharply on the ground glass. Set up the lights, one at either side of the camera at 45° angles from the exposure plane. Polarize the light if necessary and take an incident light meter reading on the picture plane. Place the color separation filter(s) in front of the camera and calculate the filter factor. Filters will block a certain portion of light entering the camera lens.

4. Load several sheets of Kodak Professional Copy Film #4125 into film holders and expose three sheets in the camera, one at the indicated exposure, one at one stop over, and one at one stop under. Repeat this process for each set of filters for each of the three prints. Label these and all subsequent samples. Process the film in the Hope 152 processor at 50% base speed. (Prior to processing the film, process control strips should have been run through the machine and any necessary adjustments made to chemical activity.)

5. Take visual density readings of the processed film and plot the characteristic curves. Determine the gamma of the film. Using the exposure that gave a full characteristic curve with each print, determine what steps on the target grey scales are closest in density to the chosen D-min and D-max with detail selected on the originals.

6. For each original, locate the two selected steps on the actual grey scale and determine the visual reflection density of these two steps. Using the characteristic curve of a grade 2 paper obtained by projection printing a step tablet in the enlarger to be used, find the points on the characteristic curve equal in density to the two points selected on the grey

scale for each original. Determine the log exposure range between these two points. The aim gamma for the three copy negatives is then determined as equal to this log H range divided by the density range between the two steps selected on the target grey scale.

7. Adjust the exposure times if the density range of the original is lying off the straight-line portion of the characteristic curve of the copy negative. Adjust the percent base speed of the Hope 152 processor to achieve the gamma for the copy negatives as determined in step 6.

8. For each original, expose another sheet of film with the adjusted exposure time and process with the adjusted base speed. Take visual density readings and plot the characteristic curves.

9. Place one of the copy negatives in the diffusion enlarger, matching the size of the original exactly. Lock the enlarger head onto the column. Make a test print on the appropriate paper. Adjust exposure until the D-min with detail step prints at the correct density.

10. Take density readings on the copy print at the two points chosen on the original to represent the D-min and D-max points with detail. Subtract the D-min from the D-max to determine the density range of the copy print. Compare this with the visual density range of the original.

11. Repeat steps 9 and 10 for the other two originals. Draw a tone reproduction diagram for each original and copy print.

Questions

1. What is the best method of enhancing the contrast of a low-contrast image? Why?

2. In step 5, the D-min and D-max with detail of the originals was matched with steps on the target grey scale by matching the densities produced in identically exposed and processed negatives. What is the advantage of doing this?

6.12 Experiment 11: The Use of Kodak Wratten Gelatin Filters to Minimize Stains on Photographic Materials to be Copied

Purpose

To demonstrate the use of Kodak Wratten gelatin filters to make stains on original photographs less noticeable in copy photographs.

Introduction

Photographic materials can become stained from any number of causes: oxidation; residual processing chemicals; water or beverage spills; the absorption of dyes from storage container surfaces or mounting boards; and from photographer's stamps, researcher's ink pens, and owner or institutional markings.

The appearance of stains on photographic prints can be significantly reduced by the use of filters in copying. One first views the print through a colored filter that matches as closely as possible the color of the stain. The closer the filter matches the stain, the greater the reduction in the appearance of the stain. When stains of two or more colors are present on the same print, however, things are not so simple. One stain can be reduced, but the same filter enhances the other. Combining filters for two different stains will not work, as only stains the color of the combination of filters will be reduced in appearance. If stains are muddy or grey or blackish, it is nearly impossible to minimize them with filters.

Reducing stains photographically requires the use of panchromatic films, which are sensitive to all wavelengths of visible light. This enables the photographer to eliminate or reduce the visibility of any color of stain, provided that a filter can be found to match the stain. Even panchromatic films respond with varying sensitivity to different wavelengths or colors of light. It is important to use the selected filter throughout the entire experimental process, from photographing the exposure target to photographing the original print. In this experiment, we will photographically reduce a variety of stains on a variety of photographic materials while retaining as accurately as possible the tones of the original.

Materials and Apparatus

- Kodak Separation Negative Film, Type 1, #4131
- three original photographs with stains:
    - one blackish muddy stain,
    - one yellow stain,
    - one blue or red stain
- exposure target from Experiment 5: 6.6
- diffusion enlarger
- transmission densitometer
- incident light meter
- studio copy lights
- Sinar View Camera, 4" × 5"
- 4" × 5" film holders
- Kodak Wratten gelatin filters
- Ilford Ilfobrom Galerie Paper, 8" × 10"
- Ilford Galerie processing chemicals
- Hope 152 Black-and-White Film Processor
- prepared Kodak Curve Plotting Graph Paper

Procedure

1. Choose three silver prints that have emulsions which are intact, with little image deterioration and with disfiguring stains. Choose one with a muddy, greyish stain and two with monochromatic stains. Enclose and mark the placement of each original in a Mylar sleeve as in Experiment 8: 6.9. Choose a D-min and D-max area where detail is to be retained and mark them on the sleeve of each of the prints. Determine the visual density range between these two points for each.

2. Select Kodak Wratten gelatin filters that match the stain color. Hold the filters up in front of the stain and assess the degree of reduction of the stain. Try other filters until maximum reduction is reached.

3. Using the exposure target from Experiment 5: 6.6, set up the 4" × 5" camera, easel, or copy stand and lights. Fill the frame with the exposure target and focus on the ground glass. Set up the lights on either side of the camera at a 45° angle from the picture plane.

4. Take incident light meter readings on the picture plane. Calculate the filter factor and set the correct exposure time with the aperture at f/8. Place the filter or filters in front of the lens for one of the originals.

5. Expose three sheets of Kodak Separation Negative Film, Type 1, #4131: one at the indicated setting, one at one stop over, and one at one stop under this setting.

6. Process the film in the Hope 152 film processor at 50% base speed. Use calibrated graph paper from Experiment 5: 6.6 to plot the characteristic curves of all three samples. Determine gamma for each and determine where on the characteristic curve the original print densities lie.

7. Using the characteristic curve of Ilford Ilfobrom Galerie grade 2.1K paper made by projection printing a template in the enlarger to be used, locate the densities on the characteristic curve equal to the D-min and D-max points with detail of the original. Determine the log exposure range between these points. Determine the density range between the two selected points with detail on the original. Divide the printing paper log H range with detail by the density range with detail of the original to get the aim gamma for the copy negative.

8. Expose another sheet of film with corrected exposure time and percent base speed to achieve the aim gamma and reproduce the D-min and D-max points with detail on the straight-line section of the curve.

9. When the correct exposure setting and base speed are established, replace the exposure target with the original print. Expose and process the copy negative.

10. Repeat these procedures using the other two original photographs chosen for this experiment.

11. Prepare to print the final copy negatives onto Ilford Ilfobrom Galerie paper. If necessary, first make a good print of the copy negative of the exposure target. After determining the gamma, find out where on the curve the D-min and the D-max points with detail of the original print lie. Adjust the printing exposure until they are printed on or very

near the same densities of the paper characteristic curve.

12. Adjust the exposure time for the paper where necessary, and print the copy negatives of the original prints.

13. Take tricolor and visual density readings of the stained areas of the originals. Take visual density readings at the same spots on the copy prints.

14. Chart the densities of the stains on the originals and the densities of the same areas on the copy prints. List the filter or filters used to reduce each stain.

Questions

1. Describe how the filtration system works.

2. What is the cause of the change, if any, in the development times and exposure times among the copy negatives (and prints) of the three originals?

3. Under what circumstances would one recommend photographic, rather than chemical or physical, removal of stains from a photographic print?

6.13 Experiment 12: Enhancement of Faded and Stained Prints Using Photographic Methods

Purpose

To demonstrate methods for photographically enhancing faded, stained, and extremely low-contrast black-and-white photographs.

Introduction

The effects on the image silver of photographic prints of oxidizing gases, residual processing chemicals, and poor storage conditions can cause the image quality to deteriorate badly. The fine metallic silver is easily converted to silver oxide and silver sulfide, resulting in faded and discolored images. This accounts for the yellowing and loss of detail, particularly evident in the highlights (low-density areas), and the overall compression of the density range.

Photographic enhancement of the image can help to make some of the detail of the original more visible by increasing the contrast between image tones. A suitable film for this purpose is a high-contrast, continuous-tone material with a long straight-line portion to its characteristic curve. It must be panchromatic, so that color filters can be used to reduce staining and/or increase image contrast.

Unlike previous experiments in this chapter, the evaluation of the results of photographically enhancing a photographic print is more subjective.

It is impossible to rely totally on densitometric analysis, because one must alter the appearance of the original image in the copy print. It is important, however, to carefully monitor, visually and using tone reproduction diagrams, the shadow and highlight tones of the copy print. As usual, the density range of the original must be copied in such a way that the range falls on the straight-line portion of the characteristic curve of the copy negative film. In this case, the printing material will be chosen on the basis of the copy negative's density range with detail equalling the useful log exposure range of the print material.

Materials and Apparatus

- Kodak Contrast Process Pan Film #4155
- Kodak Wratten gelatin filters
- Sinar View Camera, 4" × 5"
- film holders, 4" × 5"
- incident light meter
- polarized light source
- polarizing filter for camera lens
- Hope 152 Black-and-White Film Processor
- photographic papers
- photographic print processing chemicals
- transmission densitometer
- reflection densitometer
- diffusion enlarger
- exposure template from Experiment 5: 6.6
- faded and discolored photograph
- low contrast photograph

Procedure

1. Select two original photographs to be copied, one that is faded evenly across the entire surface and discolored and one that is extremely low in contrast. Determine one D-max and one D-min point (both with barely discernible detail) on each print. Mark these points and the placement of each original on a Mylar sleeve. Take visual density readings at these two points and match them to the corresponding steps of the exposure template grey scale. Determine the density range by subtracting D-min from D-max with detail on both the originals and the Q-13 gray scale. The two numbers should be very close.

2. Set the exposure template on an easel or copyboard, set up the view camera to photograph it, and place two lights on either side of the camera, at 45° angles from the picture plane. Fill the frame with the template and focus on the ground glass. Take an incident light meter reading and check for even illumination.

3. Polarize the light source using a coin as outlined in Experiment 5: 6.6. Remember that full polarized light may add as much as three stops to the exposure time. Adjust the indicated exposure time accordingly. If there are any colored stains on the print, attempt to reduce them by testing various colored filters in front of the print. If, for example, all whites have darkened to yellow, causing some

reduction in contrast, try various yellow filters. If Kodak Wratten gelatin filters are required, determine the filter factor and adjust the exposure setting.

4. Select a grade of Ilford Ilfobrom Galerie printing paper with a scale index as close as possible to the density range determined in step 1 of this experiment. Using the characteristic curve of that paper made by projection printing a template in the enlarger to be used, locate the D-min useful and D-max useful points. Determine the log exposure range between these points. Divide the printing paper's useful log H range by the density range with detail of the original to get the aim gamma for the copy negative.

5. Load several sheets of Kodak Contrast Process Pan Film #4155 into film holders, and expose for the indicated time and f-stop, bracketing exposures by one stop over and under the indicated setting. Label these and all samples.

6. Before processing the film, be sure the Hope 152 processor is up to temperature. Run through clean-up film and process control strips. If the machine is ready, process the film at 50% base speed.

7. On calibrated graph paper, draw the characteristic curve and determine the gamma. If the image tones lie on either the toe or the shoulder, adjust the exposure time accordingly. If the gamma is lower than the aim gamma, reduce the percent base speed of the processor. If the gamma is too high, increase the percent base speed of the Hope 152 processor. Once the proper exposure and development conditions have been determined, expose the original.

8. Make a print of the exposure template copy negative. Adjust the exposure time so that the D-min with detail of the original print falls on the useful D-min of the paper.

9. Make a print from the copy negative of the original print, using the exposure time determined in step 8. Make a visual comparison between the original photograph and the copy. Examine the copy print for any loss of detail in the highlights and shadows. Make a second exposure if necessary. Try another grade of paper, to see if this achieves a more aesthetically pleasing result. To a greater extent than elsewhere in this chapter, the successful copying of faded and stained images relies on the conservator's judgment.

10. Repeat these procedures for the second photograph. Draw tone reproduction diagrams for both of the prints copied.

Questions

1. What other types of films might be useful in the photographic enhancement of faded prints?
2. In this experiment, the two end densities where detail must be rendered accurately were printed on the useful D-min and useful D-max of the printing paper. What other techniques can you suggest to determine exposure and processing of the internegative to produce aesthetically pleasing results?

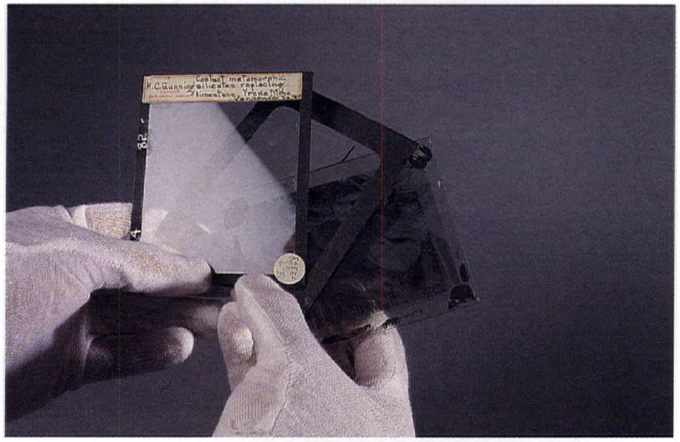


Fig. 6.6: The structure of a lantern slide.

6.14 Experiment 13: Lantern Slides: Internegative Exposure Calculations

Purpose

To construct an exposure template for use in the duplication of lantern slides, to determine the correct exposure and development times for the internegative, and to determine the log exposure values for its characteristic curve.

Introduction

There are three main differences between lantern slide duplication and negative duplication:

1. The lantern slide is a positive image, requiring the production of an internegative.
2. For expediency, and to protect the lantern slide emulsion, the cover glass is not removed, making direct emulsion contact with the duplicating film impossible.
3. The exposure light source is a light box, instead of an enlarger or point light source.

Because the lantern slides are left intact, the exposure template must also be placed between two pieces of glass that are as close as possible in thickness to the original pieces. The glass will make a difference in density readings, which must all be taken through glass in this experiment.

This experiment is the first of three concerned with the duplication of lantern slides. Experiments 15: 6.16 and 16: 6.17 complete the work started here.

Materials and Apparatus

- Kodak Separation Negative Film, Type 1, #4131
- Kodak photographic step tablet no. 2
- R.I.T. Alphanumeric Resolution Test Targets
- Kodak Aero Leader #5986
- black paper
- black masking tape
- 2 pieces of single diamond glass, 3 1/4" x 4"
- Leitz light box
- Sinar View Camera, 4" x 5"
- film holders, 4" x 5"
- footcandle meter
- transmission densitometer
- photographic light meter
- Hope 152 Black-and-White Film Processor
- Kodak Curve Plotting Graph Paper
- lantern slide

Procedure

1. Construct the new exposure template by cutting a Kodak photographic step tablet no. 2 into two equal lengths and inserting them into a 3 1/4" x 4" piece of Kodak Aero Leader. Take five sets of three R.I.T. Alphanumeric Resolution Test Targets, measuring approximately 0.5 x 1.5 cm, and insert them into the same piece of aero leader, one in each corner, and one in the center. Cut out a mask 3 1/4" x 4" in overall dimensions from the black paper, leaving spaces for the resolution targets and step tablet. Sandwich the targets and step tablet between two pieces of glass, 3 1/4" x 4", and tape the edges with black tape. Take visual density readings of all steps of the step tablet through the glass, using the 1-mm aperture of the densitometer.

2. Calibrate a sheet of Kodak Curve Plotting Graph Paper by using the density differences between the steps of the original step tablet. Make several photocopies of the calibrated paper.

3. Carefully examine the lantern slide to be duplicated. Choose a D-min and D-max point, each where detail is to be retained. Cut out a Mylar overlay for the lantern slide, on which the two density points are circled and punched out. Take density readings at these points and record them. Subtract the D-min detail from the D-max detail value to determine the useful density range of the original. Match these points with specific steps on the exposure template step tablet.

4. Place the exposure template on the light box and mask the surrounding area using the opaque curtains attached to the box. Set up the view camera and focus the exposure template on the ground glass. Measure exactly the size of the lantern slide. Adjust the camera so that the image on the ground glass matches this. To ensure 1:1 duplication, they must be exactly the same size. Make the necessary adjustments and lock the camera tightly into position. The camera and light box must be carefully secured as masks and

interpositives will be made in later work which must be in precise register.

5. Remove the exposure template from the light box and take a reflection light meter reading. Set the ISO rating at 100. Return the template to the light box. Using a reflection light meter, read the step of the step tablet closest to 0.75 in density as though metering a neutral grey card placed in a normal pictorial scene. Set the ISO rating at 100.

6. Calculate the bellows factor if the length of the bellows in millimeters exceeds the focal length of the lens, using the following formula:

$$\begin{array}{c}\text{Indicated f-stop}\\ \text{(from exposure meter)}\end{array} \times \frac{\text{Lens extension (lens to film distance)}}{\text{Focal length of lens}} = \text{Effective f-stop}$$

To get correct exposure, the effective aperture must be opened up by an amount equal to the difference between the indicated f-stop from the exposure meter and the effective f-stop.

Example:

Recommended exposure from exposure meter = f/8 at 1 second

$$\frac{\text{indicated f-stop} \times \text{lens extension}}{\text{lens focal length}} = \frac{8 \times 280\text{ mm}}{210\text{ mm}} = \frac{2240}{210} = 10.6$$

Effective f-stop = f/10.6

f/10.6 is approximately one stop from the indicated f/8. Therefore, open the aperture one stop for a new adjusted exposure of f/5.6 at 1 second.

7. Expose three sheets of Kodak Separation Negative Film, Type 1, #4131; bracket one stop over and one stop under the indicated exposure.

8. Process the film in the Hope 152 processor at 50% base speed.

9. Take visual density readings and plot the characteristic curves of each exposure on the calibrated graph paper. Determine the gamma.

10. Locate the selected D-min and D-max points with detail from the original lantern slide on the characteristic curve of the copy film.

Questions

1. Why is the diffuse illumination of the light box used rather than the collimated light of a condenser enlarger?
2. Taking density readings through the glass leads to some degree of error. How do the values of the step wedge differ when read in the glass and not in the glass? After reading Experiment 10: 6.11, what method can you suggest to overcome this problem?

6.15 Experiment 14: Lantern Slides: Time/Gamma Curves for Internegatives

Purpose

To produce a time/gamma curve for the film type used in the experiments for lantern slide internegatives.

Introduction

As discussed in Experiment 1: 6.2, the slope of the straight-line portion of the characteristic curve of a film is adjusted by changes in development time. As development time increases, so does the gamma of the film processed in a particular developer (assuming that a consistent developing method is used throughout). In these experiments, lantern slide duplication is done by first making an internegative in a camera and then contact printing the duplicate positive. Since exposure is done using a camera, a certain degree of flare is inevitable. The degree of flare and its effect on tone reproduction will change with each image. However, as a starting point it is worthwhile to create a new time/gamma curve for the internegative material that will be used under the conditions of actual use.

The two-step internegative/positive duplication method uses the Hurter and Driffield concept of "perfect objective scene reproduction." This concept is based on the slope product rule, which states that "the product of the slopes of the negative and positive characteristics at corresponding points must be equal to unity over the range used, that is, $\tau_n \times \tau_p = 1.0$" (Spencer, 1947). It is essential that this rule be followed, to reduce the possibility of expansion or compression of tones in the final duplicate positive. In this case using the selected film type (separation negative film), the optimum gamma is 1.0 for each stage of reproduction. The development time is determined by subjecting film samples exposed at the same time to a number of different processing times in the same developer. The resulting gammas are then calculated from the characteristic curves of each sample and a time/gamma curve is constructed. From this curve, a processing time that yields the required gamma can be extrapolated.

Materials and Apparatus

- Kodak Separation Negative Film, Type 1, #4131
- exposure template from Experiment 13: 6.14
- lantern slide
- prepared Kodak Curve Plotting Graph Paper from Experiment 13: 6.14
- transmission densitometer
- Hope 152 Black-and-White Film Processor
- Leitz light box
- Sinar View Camera, 4" × 5"
- film holders, 4" × 5"

Procedure

1. Turn on the Hope 152 film processor and allow it to come to temperature. Run clean-up film through the machine, and process control strips to check chemical activity levels. If necessary, make adjustments so that the processor is operating within its control limits.

2. Return to the lantern slide duplication equipment set up during Experiment 13: 6.14. Using the exposure template and exposure time from that experiment, expose nine 4" × 5" sheets of Kodak Separation Negative Film, Type 1, #4131. Label each sample.

3. Process the films in the Hope 152 processor, each at a different percent base speed: 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90% base speed.

4. Read all the visual densities and plot all the characteristic curves using the calibrated graph paper from Experiment 13: 6.14.

5. Determine the gamma for each of the film samples. Using gamma as the vertical axis and percent base speed as the horizontal axis, construct a development time/gamma graph for Kodak Separation Negative Film, Type 1, #4131. Construct the time/gamma curve.

6. From the time/gamma curve, determine the percent base speed required to give a gamma of 1.0.

7. Using this development time and the exposure determined in Experiment 13: 6.14, make an internegative from the exposure template.

8. Take density readings and plot the characteristic curve. Determine gamma and locate the density range on the characteristic curve. If gamma equals 1.00 ± 0.05 and the density of the original lies on the straight-line portion of the characteristic curve, further adjustments are unnecessary. If the density range of the original cannot be fit within the straight-line portion of the characteristic curve, expose the film so that the D-max with detail of the original is as close as possible to the toe while still being on the straight-line portion.

9. Replace the exposure template with the original lantern slide on the light box. Produce an internegative using the exposure and development times from steps 6 and 7 above.

6.16 Experiment 15: Duplication of Lantern Slides

Purpose

To demonstrate the production of lantern slide duplicates using both masked and unmasked internegatives.

Introduction

The duplication of black-and-white lantern slides requires that all of the densities of the original be reproduced as accurately as possible on the materials used for duplication. Although the absolute densities at different stages of the duplication process may vary, the density differences (ΔD) will remain the same, providing that a gamma of 1.0 and a straight-line tone reproduction plot is achieved in the duplication procedure.

A Kodak photographic step tablet no. 2 is used to establish the exposure and processing times for the film used for duplicating. Once a gamma of 1.0 is established, the D-min and D-max densities with detail of the original are matched with corresponding densities on the step tablet. These selected densities are used to monitor the duplication at both the internegative and duplicate positive stages.

The D-max with detail of the original should be placed as low as possible on the straight-line portion of the internegative — approximately 0.40. An internegative is made using the original lantern slide. The densities of the internegative are measured. The ΔD of the internegative step tablet forms the log H axis for the duplicate lantern slide. The film used for the duplicate lantern slide is then tested for exposure and time/gamma. When the correct exposure/development times are found, the duplicate lantern slide is made.

If the density range of the original cannot fit within the straight-line portion of the internegative, some compression of the highlight values will occur. This may cause the highlight (clear) areas on the duplicate lantern slide to appear clearer than, and lacking in detail found on, the original. In this case, a second duplication procedure is called for, which incorporates the use of a mask (anon., 1935). At the internegative stage, it is sometimes necessary to make a shadow mask. This mask acts to increase the contrast of the shoulder area of the internegative film. The mask contains a low contrast image of only the parts of the image that were rendered on the shoulder of the interpositive material. In the other areas, it adds only a uniform "base plus fog" density. The required gamma, density range, and densities can be calculated, for a mask to be used to increase the density of the shadows (high density areas) of the internegative. Use the following formula:

$$\frac{\Delta D\ \text{Duplicate}}{\Delta D\ \text{Original}} \times 100\% = \%\ \Delta D$$

Example:

$$\frac{1.10}{1.33} \times 100 = 82\%$$

The density range of the duplicate lantern slide is 82% as long as the density range of the original lantern slide. To match the density range of the original, the density range of the duplicate must be extended another 18%. (100% - % ΔD = % ΔD required.)

$$\frac{1.0}{100} \times 18 = 0.18$$

D-max = 1.55 D-min = 0.22

$1.55 \times 0.18 = 0.28$ $0.22 \times 0.18 = 0.04$

ΔD of the mask = 0.28 - 0.04 = 0.24

ΔD = 0.24

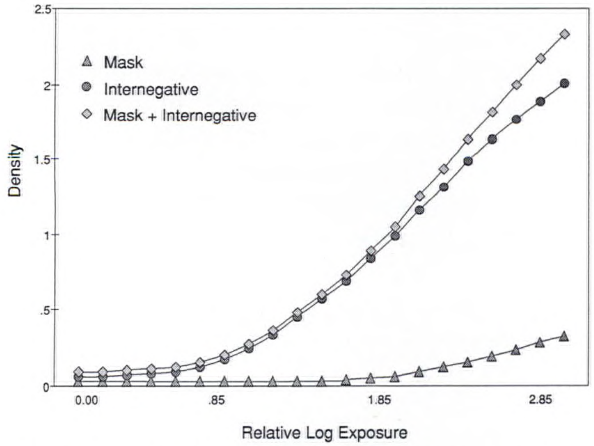


Fig. 6.7: Addition of internegative and mask densities.

Materials and Apparatus

- Kodak Separation Negative Film, Type 1, #4131
- Kodak Pan Masking Film #4570
- exposure template from Experiment 13: 6.14
- internegative of exposure template from Experiment 14: 6.15.
- internegative of original lantern slide, Experiment 14: 6.15.
- contact printing frame
- diffusion enlarger
- Kodak Curve Plotting Graph Paper, uncalibrated, and prepared from Experiment 13: 6.14
- transmission densitometer
- Sinar View Camera, 4" × 5"
- film holders, 4" × 5"
- Leitz light box
- Hope 152 Black-and-White Film Processor
- glass, single diamond, 3 1/4" × 4" pieces
- Kodak Pin Register Frame
- tape
- Japanese tissue dyed black
- PVA emulsion
- black paper

Procedure

1. Read and record all the visual densities of the internegative exposure template from Experiment 14: 6.15. Determine the density differences between each step of the step wedge and calibrate a sheet of Kodak Curve Plotting Graph Paper using these values. Make several copies of this calibrated sheet.

2. Using the internegative exposure template, prepare to produce a duplicate lantern slide. Kodak Separation Negative Film, Type 1, #4131 will be exposed in a contact printing frame with the internegative. Place the contact printing frame on the base of the enlarger, raise the enlarger head, unfocus the lens, and set the aperture at f/8. Make several test exposures, label them, and process them in the Hope 152 film processor at 50% base speed.

3. Record the step tablet densities and draw the characteristic curves. A gamma of 1.0 is required and the D-min value of the original lantern slide should be sitting on the straight-line portion of the curve, at a density of approximately 0.40.

4. Take more exposures, making the necessary adjustments to exposure and development times. Label each sample.

5. Once the correct exposure and development times are achieved, replace the internegative exposure template with the internegative of the original. Make a duplicate lantern slide using the times determined in step 4 above.

6. Draw the characteristic curve of the duplicate exposure template. Visually compare the duplicate with the original lantern slide. Take density readings of the duplicate lantern slide at the same points used on the original, to determine the density range. Determine the density range of the duplicate lantern slide.

7. If the density range of the duplicate is less than the original and the highlights are slightly muddy, masking will be required. Using the formula given in the introduction above, determine the percentage masking required. Determine the D-max with detail, the density range, and the gamma of the mask.

8. To produce the mask, place the exposure template from Experiment 13: 6.14 on the Leitz light box. Be sure the size is exactly the same as the original lantern slide. Focus the image on the ground glass of the view camera, then slightly unfocus the lens. (Later, when registering the mask with the internegative to produce the duplicate, a slightly out-of-focus mask will result in a sharper duplicate lantern slide.)

9. Using Kodak Pan Masking Film #4570, make and label several test exposures and process them in the Hope 152 processor. (The required density range and gamma of the mask were calculated in step 7 above.) Begin by taking light meter readings of the light box using the manufacturer's recommended ISO rating for this film. Process the film at 50% base speed.

10. When the correct densities have been achieved for the highlight mask, take complete density readings. Using a piece of calibrated graph paper from Experiment 13: 6.14, draw the characteristic curve and calculate the gamma.

11. Replace the exposure template with the original lantern slide on the light box. Make a mask for the original, using the times determined in step 9 above.

12. Place the exposure template mask and the exposure template internegative in exact registration. Using thin strips of tape, secure them. Place the masked internegative into a Kodak Pin Register Frame, emulsion side away from the glass. Place a piece of Kodak Separation Negative Film, Type 1, #4131 in direct contact, emulsion to emulsion. Replace the back of the printing frame and expose the film exactly as the first unmasked duplicate was exposed. (Follow steps 4 and 5 above.) Exposure time and development percent base speed should be identical to the unmasked duplicate.

13. Take density readings of the masked duplicate step tablet. To calibrate the graph paper so that this characteristic curve can be drawn, add up the densities of the internegative with the densities of the interpositive mask. Subtract the steps, one from the next, and use these values to calibrate the log exposure axis. Plot the characteristic curve of the masked duplicate positive of the exposure template.

14. Replace the exposure template internegative and mask with the original internegative and corresponding mask. Expose and develop the duplicate lantern slide, following the procedure outlined in step 12 above.

15. Compare the unmasked duplicate with the masked duplicate, and compare both with the original. Take density readings at the same points on all three slides. Chart these densities and compare the results.

16. Using a microscope, determine the resolving power of the film at the internegative stage and at the duplicate stage, both masked and unmasked. Record the values in chart form.

17. Draw tone reproduction diagrams for both the masked and unmasked duplicate lantern slides.

18. Cut out a black paper mat that exactly matches the mat found inside the original lantern slide package. Place it on the emulsion side of the duplicate lantern slide and sandwich them between two pieces of glass, 3 1/4" x 4". Using strips of Japanese tissue dyed black and PVA emulsion, seal the package along all four sides. Do this for both the masked and unmasked duplicate lantern slides.

Questions

1. How does the glass cover of the lantern slide affect the image densities?
2. Why is the highlight area mask used?
3. How do you account for the loss of resolution between the internegative and duplicate lantern slides?

6.17 Experiment 16: Comparing Original and Duplicate Lantern Slides

Purpose

To demonstrate three methods of evaluating the quality of a duplicate lantern slide.

Introduction

To ensure that the duplicate lantern slide is actually a duplicate, that is, one which is the same in image quality and tone reproduction as the original, three methods of evaluation may be used:

1. A tone reproduction diagram demonstrates in graphical form how the tones in the duplicate compare with those of the original lantern slide. This is done by plotting the densities of the duplicate, in relation to the densities of the internegative and original lantern slide, on a four-quadrant graph. The fourth quadrant is used to show the comparison of the tone reproduction of the duplicate negative with the tones of the original negative. This method uses a photographic step tablet as a vehicle for comparison and is described in Experiment 3: 6.4.
2. Density values taken directly from the original lantern slide and the duplicate lantern slide can be recorded and used as a comparative measure. This method uses the densities of the original lantern slide as a base line for a bar chart. The density difference between selected areas on the original and duplicate lantern slide is shown in a positive/negative form from the base line in a bar chart.
3. The original and duplicate lantern slides can be compared using projected images of each lantern slide. The original and duplicate lantern slides are placed into projectors with very similar qualities and then enlarged by projection onto the screen. The images are placed beside each other so that any imperfections, such as loss of resolution, fine detail, or image density, as well as flaws in the handling and processing of the duplicate, will become apparent. This third procedure will have limited use, depending upon the availability of lantern slide projectors.

Materials and Apparatus

- original lantern slide from Experiment 14: 6.15
- exposure template from Experiment 14: 6.15
- internegative from Experiment 14: 6.15
- duplicate lantern slide from Experiment 14: 6.15
- graph paper for tone reproduction diagram
- graph paper for bar chart
- 2 lantern slide projectors

Method A —Tone Reproduction Diagram: Procedure

1. From Experiment 14: 6.15, assemble the visual density values of the original exposure template step tablet, the internegative step tablet, and the duplicate positive step tablet.

2. Following the procedure outlined in Experiment 3: 6.4 for making a tone reproduction diagram, take a piece of graph paper, divide it into four quadrants, and plot the densities of the original step tablet in the lower right quadrant. The horizontal axis is read from right to left in ascending values and the vertical axis from top to bottom in ascending values. The densities should form a straight line running diagonally across the quadrant. (See illustration in Experiment 3: 6.4.)

3. Quadrant II, the lower left quadrant, represents the internegative step tablet. Draw straight lines parallel to the horizontal axis from each of the density points in Quadrant I through Quadrant II. These represent the log H values for Quadrant II. On these lines, plot the densities of the internegative; if a mask was used, plot the densities of the internegative after the mask densities for each step have been added to them. The horizontal axis is the density axis, the values ascending from right to left. The result should be a characteristic curve with a slight shoulder and a slight toe region.

4. Draw straight lines parallel to the vertical axis from each of the density points plotted in Quadrant II and extend them into Quadrant III. These represent the log H values for quadrant III. The density axis is the vertical axis in Quadrant III, and values increase from the center of the graph upwards. On the log H lines from Quadrant II, plot the density values of the duplicate positive.

5. Draw straight lines parallel to the horizontal axis from the density points plotted in Quadrant III, and extend them through Quadrant IV. Extend parallel lines up from the density values plotted in Quadrant I. The line formed by joining the points at which these two sets of parallel lines meet in Quadrant IV represents the actual tone reproduction. If the tone reproduction is perfect, the line should be the mirror image of the line in Quadrant I. (Some variation is tolerable, however.) Draw a straight line along the straight-line portion of the curve in Quadrant IV that is a 45° angle from the

horizontal axis. This indicates how close the tones are actually matched.

6. Take the D-min and D-max with detail for the original lantern slide and match these densities with specific steps on the original step tablet. Mark these two points on the line in Quadrant I, and on the curves in Quadrants II, III, and IV. Draw lines connecting the points on the tone reproduction diagram. This provides a graphic demonstration of the location of the original negative's density range, in relation to the tone reproduction of the step tablet.

7. Complete a tone reproduction diagram for both the masked duplicate and the unmasked duplicate.

Method B — Density Value Comparison: Procedure

1. On a piece of graph paper, using the length of the paper for the horizontal axis, draw a line through the graph from right to left. This line represents the density values of the original.

2. Place the original lantern slide, emulsion side up, inside a Mylar sleeve, marking its exact placement. Circle 10 areas and punch them out representing the full range of image tones, from D-min to D-max. Take visual density readings at these 10 spots. Number the areas from 1 to 10.

3. Place the duplicate lantern slide in the Mylar sleeve with the 10 areas circled. Take and record visual density readings of the duplicate at these 10 numbered areas.

4. Using the same Mylar sleeve, take and record density readings at the circled areas on the masked duplicate lantern slide.

5. The straight line of the graph represents the density readings of the original lantern slide. Any changes occurring in the densities between (1) the original and the unmasked duplicate, and (2) the original and the masked duplicate are indicated by bars projecting vertically from the horizontal axis.

   The 10 areas at which density readings were taken are indicated as vertical columns crossing the original densities line. The columns are numbered from left to right in numerical order. On the vertical axis at the extreme left of the graph, mark density values at regular increments. Indicate 0.20 and 0.40 density values above the horizontal axis (0.00 line), and 0.20 and 0.40 below the horizontal axis. Be sure the increments are large enough to show the actual density values.

6. Subtract the density of area 1 of the unmasked duplicate from the density of area 1 of the original. Do the same for each of the numbered areas, from 2 through 10. Take this ΔD value and place it on the bar chart. If

density is added, it becomes a positive density value and is indicated by a bar above the horizontal axis. If density is lost, it becomes a negative density value and is represented as a bar below the horizontal axis.

7. Repeat the procedure outlined in step 6, using the density values of the masked original.

8. Be sure the chart is well labelled, so that masked and unmasked duplicates can be easily compared to each other, as well as to the original lantern slide.

Method C — Enlarging the Image by Projection: Procedure

1. This method will have limited use, depending on the availability of lantern slide projectors. Ideally, the projectors should have identical lenses and light sources. In this procedure, we place the original lantern slide in one projector and the duplicate in another projector and project the images at exactly the same size, side by side. Magnification should be about 30 times to 40 times.

2. Make a visual examination of the projected images and note any differences between the masked and unmasked duplicates and the original. Look for loss of resolution, change in image density, and possible processing flaws.

Questions

1. Discuss any flaws in the methods for image comparison.

2. Where are the losses in image detail likely to occur in the duplicate lantern slide?

3. What corrective measures can be taken to reduce image detail losses?

6.18 Experiment 17: Masking of Wet Collodion Negatives

Purpose

To demonstrate the use of masks to increase or decrease the contrast of duplicate negatives, so that they can be printed on contemporary print materials with no loss of highlight or shadow detail.

Introduction

The wet collodion process was invented by F. Scott Archer in 1851 and was most widely used for glass plate negatives (and ambrotypes, a negative image on glass which appears positive). Wet collodion glass plate negatives were most widely used in conjunction with albumen papers. The resulting prints were extremely fine-grained, with a very long tonal range. This is due to the long density range of the collodion negatives and the log exposure range of albumen papers. Contemporary black-and-white printing papers have a much shorter log exposure range than albumen papers. Therefore, to attempt to print the long density range of collodion plates or their duplicates onto contemporary papers would result in a loss of tones in the highlight or shadow regions. Highlight and shadow tones found in the negative would become compressed and lost on the shoulder and/or toe region of the characteristic curve of the photographic paper.

Masks can make it possible to print a long density range negative on a paper with a shorter log exposure range. They can be either positive or negative and are printed in register with either the original or the duplicate negative. *Positive masks* reduce contrast and can have an overall or local effect. *Negative masks* are used to increase contrast and are used for local or overall effect. The degree of masking required is dependent on two factors: the density range of the negative, and the log exposure range of the contemporary print material.

The masking approach used here calculates mathematically the degree of masking needed, using the following formula:

$$\frac{\Delta \text{D duplicate (print scale index)}}{\Delta \text{D original (negative density range)}} \times 100 = \%\,\Delta\text{D}$$

$$100 - \%\,\Delta\text{D} = \text{the percentage of the original densities to be masked.}$$

The density range of the original must be reduced by a certain percentage in order to be accommodated on a contemporary printing material. If, for example, a 33% reduction in density range is required, the mask will have densities that are 33% of the original.

Example:

duplicate negative density range = 2.11
paper log exposure range (scale index) = 1.43

$$\frac{1.43}{2.11} \times 100 = 67\%$$

$$100 - 67\% = 33\%$$

Therefore, a reduction mask of 33% is required.

D-max of the negative = 2.60

D-min of the negative = 0.49

$$2.60 \times 33\% = 0.8580$$

$$0.49 \times 33\% = 0.1617$$

Therefore, ΔD of the mask = 0.8580 - 0.1617 = 0.70

Subtracting the ΔD of the mask from the ΔD of the original negative or duplicate negative should give the log exposure range (scale index) of the contemporary print material, or should come close to the range.

$$2.11 - 0.70 = 1.41$$

That example deals with making a *positive* mask to *reduce* the contrast and density range of a historical negative. To *increase* the contrast and density range, one would make a *negative* mask from the interpositive and print it in register with the negative to add a specific percentage density to the negative.

Example:

duplicate negative density range = 1.00
paper log exposure range = 1.50

$$\frac{1.50}{1.00} \times 100 = 150\%$$

150 - 100 = 50% more density required

D-max of negative = 1.20 × 50% = 0.60
D-min of negative = 0.20 × 50% = 0.10

density range of mask (ΔD) = 0.60 - 0.10 = 0.50

Adding the density range of the mask to the density range of the negative should equal the log exposure range (scale index) of the chosen printing paper.

$$1.00 + 0.50 = 1.50$$

Materials and Apparatus

- Kodak Separation Negative Film, Type 1, #4131
- Kodak Pan Masking Film #4570
- 2 wet collodion glass plate negatives
- Ilford Ilfobrom Galerie Paper, grade 1.1K
- Ilford Galerie processing chemicals
- Hope 152 Black-and-White Film Processor
- footcandle meter
- incident light meter
- contact printing frame
- pin register printing frame
- condenser enlarger
- diffusion enlarger
- transmission densitometer
- reflection densitometer
- 2 pieces of glass, 8" × 10"
- Kodak Kodapak Sheet (matte)
- exposure template from Experiment 2: 6.3
- prepared Kodak Curve Plotting Graph Paper from Experiment 2: 6.3

Procedure

1. Select two wet collodion negatives: one with an extremely long density range (greater than 1.90), and one very low-contrast negative (density range around 0.70). Select a contemporary printing paper with a log exposure range around 1.40. Choose two areas on each of the negatives: one representing D-max with barely discernible detail, and one representing D-min with barely discernible detail. Mark each negative's position and the two areas on a Mylar sleeve. Record visual density values for these points.

2. On the exposure template from Experiment 2: 6.3, select the step numbers that have density values closest to the D-min and D-max of the original negatives.

Part I — Positive Mask for Negative with Extremely Long Density Range: Procedure

1. Place Kodak Separation Negative Film, Type 1, #4131 and the exposure template from Experiment 2: 6.3 in contact emulsion-to-emulsion in the contact printing frame under the diffusion enlarger. Make several test exposures for the production of an interpositive. Label all samples. Take careful foot-candle meter readings at the exposure plane.

2. Process the film in the Hope 152 processor at 50% base speed. Plot the characteristic curves of the processed samples on the calibrated graph paper from Experiment 2: 6.3. Determine the gamma and the placement of the density range of the original negative on the characteristic curve. If gamma equals 1.0 and the D-min and D-max values with detail of the original lie on the straight-line portion of the curve, no further testing is required. If further testing is required, adjust the exposure time and development accordingly. (The procedure is fully outlined in Experiment 2: 6.3.)

3. Once a suitable interpositive of the exposure template has been produced, replace the exposure template with the original negative. Using the corrected exposure time and development time, produce an interpositive from the original negative.

4. Using the procedure outlined in Experiment 2: 6.3, produce a duplicate negative from the interpositive. Make sure that the tones are reproduced one-to-one (or as close as possible). Complete a tone reproduction diagram for the duplicate negative.

5. Produce the best possible print from the duplicate negative, using Ilford Ilfobrom Galerie 1.1K paper. Process the print using Ilford Galerie processing chemicals and procedure. Use the diffusion enlarger to produce the photographic print.

6. Calculate the density range of the duplicate negative using the same D-min and D-max points determined on the original negative in step 1. The density range of the duplicate should be the same as the original.

7. Determine the percentage of masking required to print the duplicate negative onto Ilford Ilfobrom Galerie 1.1K paper, with no loss in the highlights or shadows. (Use the formula given in the Introduction, above.) Multiply the D-min and D-max values of the duplicate negative by the percentage of masking required. From this, determine the density range of the mask.

8. Kodak Pan Masking Film #4570 is the film used here for mask production. When choosing a film to make the mask, it is important to consider which area of the negative requires the greatest masking. When

attempting to increase the density range of a negative, it may be necessary to add more density to the high density areas of the negative and leave the low density areas virtually untouched. This is accomplished by using a high-contrast film such as Kodak Kodalith Ortho Film Type 3. (A mask made from this film will add density only to the high density areas of the negative.)

The original exposure template step tablet is used to determine the correct exposure and development times for the positive mask. When making masks, it is best to have them slightly out of focus, so that registering them is less critical at the printing stage. Because the mask is contact printed, a diffusion screen is placed between the step tablet and the masking film, to reduce the sharpness of the image. The step tablet and diffusion screen are sandwiched between two 1/4" thick pieces of glass, and then laid on top of the pan masking film, which is lying emulsion-side up on a flat black surface. The step tablet emulsion is facing down. The glass keeps everything flat and in good contact. The second piece of glass between the diffusion screen and the masking film also contributes to the diffusion of the mask image. Due to the number of components in the sandwich, it may be necessary to use a condenser enlarger for more light.

9. Prior to making the film sandwich, take incident light meter readings at the film plane and determine exposure time and aperture. Assemble the sandwich and make several test samples. Label all samples. Process them in the Hope 152 processor at 50% base speed.

10. We have determined above the D-max and D-min for the original negative and for the mask. The corresponding steps of the Kodak photographic step tablet no. 2 were noted. If, for example, the D-min of the original negative was located on step 20 of the original step tablet, step 20 on the mask (a positive image) should be the D-max area with barely discernible detail. The same is true of the D-min areas of the step tablet and mask. To precisely determine the required D-max density value of the mask at step 20, add the density range calculated for the mask to the "base plus fog" of the mask.

Example:

Original negative D-max = 1.90
step 4 of tablet
Original negative D-min = 0.40
step 20 of tablet
Original negative ΔD = 1.50

Contemporary printing paper log exposure range = 1.00

Mask required:

$$\frac{\Delta D \text{ duplicate (print scale index)}}{\Delta D \text{ original negative}} \times 100$$

$$= \frac{1.00}{1.50} \times 100 = 67\%$$

Percentage masking required: 100 - 67 = 33%

Positive mask densities required:

D-max = 1.90 × 33% = 0.6270
  step 20 of step tablet
D-min = 0.40 × 33% = 0.1320
  step 4 of step tablet
ΔD = <u>0.4950</u>

Therefore, the density of step 20 of the mask (the D-max with barely discernible detail) should be 0.4950 above "base plus fog".

11. Take density readings of your test exposures at the D-max point with barely discernible detail. If it equals the sum of the density range and "base plus fog," replace the exposure template with the duplicate negative and make the positive mask for the negative. If not correct, adjust the exposure time and development time accordingly.

12. Once the final mask for the negative has been produced, print the negative and mask onto the selected printing paper using a pin register contact printing frame with the diffusion enlarger. Process the print according to procedures outlined in Chapter 4.

13. Draw a tone reproduction diagram for the unmasked and masked negative. Quadrant I represents the interpositive, Quadrant II the duplicate negative and mask where applicable, and Quadrant III the print.

Part II — Negative Mask to Increase the Tonal Range of a Negative: Procedure

1. Use the selected negative with a very narrow tonal range and the exposure template from Experiment 2: 6.3. Produce a duplicate negative on Kodak Separation Negative Film, Type 1, #4131, using the procedure outlined in Experiment 2: 6.3.

2. Select a paper on which to print the duplicate negative. Calculate the log exposure range of the print material. Using the density range of the duplicate negative, calculate the degree of negative masking required to print onto the selected material. Use the following procedure.

Example:
Duplicate negative
D-min = 0.20 (step 2 of step tablet)
D-max = 0.90 (step 7 of step tablet)
ΔD = 0.70

The log exposure range of the selected paper is 1.20

$$\frac{\Delta D \text{ duplicate (paper scale index)}}{\Delta D \text{ original (duplicate negative)}} \times 100 = \% \, \Delta D$$

$$\frac{1.20}{0.70} \times 100 = 171\%$$

171% - 100 = 71% increase required

Mask densities required:

D-min = 0.20 × 71% = 0.1420
step 2 of step tablet
D-max = 0.90 × 71% = 0.6390
step 7 of step tablet
ΔD = 0.4970

Because the mask is a negative, the density values of the duplicate and the mask are added to give the total density range of the combined negative and mask.

D-min = 0.20 + 0.1420 = 0.3420
D-max = 0.90 + 0.6390 = 1.5390
ΔD = 1.1970

1.1970 when rounded off equals the log exposure range of the selected printing paper.

3. Use the interpositive step tablet as the exposure template for making the mask. Sandwich the interpositive, together with the diffusion screen, between two pieces of glass and lay this with the emulsion down onto a piece of masking film laid emulsion up. The whole assembly should be sitting on a flat black background on the enlarger easel. Prior to making the film sandwich, take an incident light meter reading at the exposure plane and calculate the correct exposure time and aperture. Assemble the film sandwich and make several test exposures. Label all samples. Process the film in the Hope 152 processor.

4. Because the mask is a negative mask, the D-max with barely discernible detail lies on the same step of the step tablet as the original negative D-max. The density range change is caused by adding the original negative density range to the mask density range. This value should equal the log exposure range of the printing paper. Therefore the D-max value of the mask should equal the density range of the mask plus "base plus fog". Calculate this value from the test sample and adjust the exposure and development times to achieve this value for the D-max with barely discernible detail area of the mask.

5. Once the correct mask density has been achieved, replace the interpositive exposure template with the original negative interpositive and produce the final mask. Follow the exact exposure and development procedures determined in step 3 above.

6. Prepare to print the masked duplicate negative. First, however, make the best possible print from the unmasked negative. Process the print using the procedures outlined in Chapter 4.

7. Make a print from the masked duplicate in the pin register contact printing frame. Use the same exposure and development time as used for the unmasked negative.

8. Make tone reproduction diagrams for the masked and unmasked duplicate negatives. Quadrant I represents the interpositive, Quadrant II represents the duplicate (one diagram for masked and one for unmasked), and Quadrant III represents the final positive print for both.

6.19 Experiment 18: Corrective Duplication and Printing of Stained Historical Negatives

Purpose

To demonstrate procedures for photographically reducing or eliminating the stains on historical negatives during the duplication process and during printing of original negatives.

Introduction

The duplication of historical negatives is an important preventative measure against the loss of or damage to historically significant images. The corrective duplication of historical negatives not only preserves the information, but also improves the image by photographically removing disfiguring stains that may obscure part of the image during the printing of the original negative.

Contemporary photographic duplicating films, in combination with thin band separation filters, are used to photographically remove stains in the duplication process. Thin band separation filters (Kodak Wratten gelatin filters) used with a panchromatic printing paper, can eliminate stains when printing from the original negative. It is possible, using these procedures, to remove almost any colored stain, as long as it is not muddy and does not contain any grey deposits.

It is essential to use filters designed specifically for photographic use, because the manufacturer supplies filter factors for each one, allowing correct exposure calculations. They will be even in color and density across the entire surface of the filter, and of a known, specified color.

As determined in Experiment 2: 6.3, Kodak Separation Negative Film, Type 1, #4131 is an ideal film for negative duplication, because of the very long straight-line portion of its characteristic curve, which can accommodate the long density ranges of historical negatives. In addition, it is a very fine-grain film that maintains acceptable resolution.

The printing of stained negatives onto standard photographic papers that are blue sensitive illustrates that colored stains can act like photographic filters that sharply reduce the transmission of certain wavelengths of light, depending on the color of the stain. This shows on the print as less density in areas where stains exist on the negative, while unstained negative areas print normally, resulting in a blotchy, uneven print. The use of a panchromatic paper, such as Kodak Panalure Paper, and colored filters can reduce or eliminate this problem.

Fig. 6.8: Prints from an internegative made with and without filtration to reduce the photographic effect of stains.

Fig. 6.9: A slide of the original negative showing staining.

Materials and Apparatus

- 3 historical negatives:
  1 with yellow stains
  1 with muddy grey stains
  1 with red, green, or blue stains
- exposure template from Experiment 2: 6.3
- Kodak Separation Negative Film, Type 1, #4131
- Kodak Panalure Paper
- Kodak processing chemicals
- Ilford Ilfobrom Galerie paper
- Ilford Galerie processing chemicals
- Kodak Wratten gelatin filters
- 4" × 5" diffusion enlarger
- contact printing frame
- incident light meter
- transmission densitometer
- reflection densitometer
- Hope 152 Black-and-White Film Processor

Part I — Corrective Duplication: Procedure

1. Choose three historical negatives of larger format, up to 4" × 5". Each should have a different color stain. One should fall within the muddy grey range. On each negative, choose a D-min and a D-max point, both outside the stained area. Both points should have barely discernible detail. Take visual density readings at these points and from these determine the effective density range of each of the negatives. Determine which step of the exposure template (the Kodak photographic step tablet no. 2 from Experiment 2: 6.3) each of the D-max and D-min values are equal to.

2. Place the negatives one at a time on a light box. View them through Kodak Wratten gelatin filters. Match the color of the stain as closely as possible with a Wratten gelatin filter or combination of filters. When viewing the stain through the filter, it should disappear or be reduced as much as possible. When the correct filter has been selected, calculate the filter factor so that the exposure can be adjusted accordingly.

3. The interpositive will be produced by contact printing the original negative, using Kodak Separation Negative Film, Type 1, #4131, a contact printing frame and a diffusion enlarger. Take an incident light meter reading at the film plane. Determine the correct exposure time and aperture. Calculate the filter factor. Place the filter for the first negative into a Wratten filter holder and place it just below the lens in the light path. If there is sufficient light, the light meter reading can be taken with the filter in place and compared with the calculated exposure.

4. Make test exposures, bracketing one stop over and one stop under the indicated exposure. Label these samples. Process the film in the Hope 152 processor at 50% base speed. Follow the complete procedure in Experiment 2: 6.3 for the production of an interpositive.

5. Following the procedure in Experiment 2: 6.3, produce a duplicate negative from the

interpositive. Because the stain is eliminated or reduced during the production of the interpositive, the filter can be removed from in front of the enlarger lens (and the exposure adjusted accordingly) during the printing of the duplicate negative. Produce the duplicate negative by contact printing, again using Kodak Separation Negative Film, Type 1, #4131, and a diffusion enlarger as the light source.

6. By contact printing, make a print from the original negative and a print from the duplicate negative. Match the D-min and D-max points of both prints. Make a visual comparison of the results. Print on Ilford Ilfobrom Galerie paper and process using Ilford Galerie chemicals. Process according to the procedure outlined in Chapter 4.

Part II — Corrective Printing: Procedure

1. In steps 1 and 2 of Part I above, the density range of each negative was calculated, the Kodak Wratten gelatin filter(s) chosen for the stain, and the filter factor determined. We will now print the original negative with the selected Kodak Wratten gelatin filter(s), using panchromatic photographic paper. (Kodak Panalure Paper is the only commercially available panchromatic paper and is commonly used for making black-and-white prints from colored negatives.) This paper gives a grey-tone rendering of colored subjects, approximating their original brightness, as the paper is sensitive to all wavelengths of visible light. Print the negative by enlargement to 8" × 10". Process according to the procedures outlined in Chapter 4.
2. Compare all three prints, one from the original negative, one from the corrected duplicate, and one from corrective printing.

Question

1. What are the limitations of stain removal through the use of filters?

6.20 References

Anon. 1935. The Person Process. *Photographic Journal* (London) **75**: 569-570.

Spencer, D.A. 1947. Tone Rendering in the Reproduction of Photographs. *Photographic Journal* (London) **87B**: 94-104.

6.21 Supplemental Readings

Anon. 1950. Copies Without Glare: A New Technique in Copying Uses Polarized Light to Eliminate Surface Reflections. *Modern Photography,* Feb., 48-49, 110.

ANSI. 1984. *Black-and-White Continuous-Tone Papers — Determination of ISO Speed and Range for Printing.* ANSI ISO 6846-1983. ANSI PH2.2-1984. New York: American National Standards Institute.

ANSI. 1986. *Methods for Manual Processing of Black-and-White Photographic Films, Plates, and Papers.* ANSI PH4.29-1986. New York: American National Standards Institute.

Capstaff, J.G., and M. W. Seymour. 1927. Duplication of Motion Picture Negatives. *Transactions of the Society of Motion Picture Engineers* **10**(28): 223-229.

Carroll, B.H. 1980. *Introduction to Photographic Theory: The Silver Halide Process.* New York: John Wiley & Sons.

Crabtree, A.D. 1971. A Guide to the Principles of Making Duplicate Negatives. *British Journal of Photography* **118**: 890.

Crabtree, J.I., and C.H. Schwingel. 1932. The Duplication of Motion Picture Negatives. *Journal of the Society of Motion Picture Engineers* **19**: 891-908.

Crawford, William. 1979. *The Keepers of Light.* Dobbs Ferry, N.Y.: Morgan & Morgan.

Croy, O.R. 1964. *Camera Copying and Reproduction.* Trans. L. A. Mannheim. New York: Focal Press.

Denstman, H. 1973. Copy Negatives: Original Quality. *Industrial Photography* **22**(11): 22-25.

Denstman, H. 1977. Illumination for Copying: It's What's in Back That Counts. *Industrial Photography* **26**(2): 29-32.

Denstman, H. 1978. Polarized Light for High Fidelity Reproduction. *Industrial Photography* **27**(10): 23-25, 60.

Eastman Kodak. 1952. *Stains on Negatives and Prints.* Kodak Photographic Notebook, no. J-18, Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1977. *Photography with Large Format Cameras.* Kodak Publication, no. O-18. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1978. *Kodak B/W Photographic Papers.* Kodak Publication, no. G-1. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1978. *Printing Color Negatives.* Kodak Publication, no. E-66. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1984. *Copying and Duplicating in Black-and-White and Color.* Kodak Publication, no. M-1. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1985. *Practical Densitometry.* Kodak Publication, no. E-59. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1985. *Quality Enlarging with Kodak B/W Papers.* Kodak publication, no. G-1. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1985. *Conservation of Photographs.* Kodak Publication, no. F-40. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1987. *Kodak Professional Black-and-White Films.* Kodak Publication, no. F-5. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. n.d. *Using Polarized Light for Copying.* Kodak Publication no. S-70-1-2. Kodak AV Equipment Memo. Rochester, N.Y.: Eastman Kodak Co.

Eaton, G.T. 1970. Preservation, Deterioration, Restoration of Photographic Images. *Library Quarterly* 40(1): 85-98.

Haist, Grant. 1979. *Modern Photographic Processing.* 2 vols. New York: John Wiley & Sons, 1: 721-742, 749.

Haney, F.J. 1978. Illuminating Your Copyboard Mathematically: A System to Measure Light Distribution Pattern. *Industrial Photography* **27**(5): 26-27.

Hepworth, T. [1894] 1978. *The Book of the Lantern: A Practical Guide to the Working of the Optical (or Magic) Lantern, With Full and Precise Directions for Making and Colouring Lantern Pictures.* [5th ed. London: Hazell, Watson, and Viney, Ltd.]. Reprint. 6th ed. New York: Arno Press.

Ives, C.I., and E. Huse. 1928. Notes on Making Duplicate Negatives. *Transactions of the Society of Motion Picture Engineers* **12**: 382-389.

Ives, C.I., and J.I. Crabtree. 1937. Two New Films for Duplicating Work. *Journal of the Society of Motion Picture Engineers* **29**: 317-325.

Jacobson, Ralph C. 1978. *The Manual of Photography.* London: Focal Press Ltd.

James, T.H., and G.C. Higgins. 1968. *The Fundamentals of Photographic Theory.* 2nd ed. Dobbs Ferry, N.Y.: Morgan & Morgan, 190-193.

Langford, Michael J. 1980. *Advanced Photography: A Grammar of Technique*. 4th ed. London: Focal Press Ltd.

Langford, Michael. 1986. *Basic Photography*. 5th ed. London: Focal Press.

Lind, E. 1938. Some Hints on the Person Printing Method. *British Journal of Photography* 85: 214-215.

Morris, O.J. 1932. Copying: Some Old Theories and Some New Methods. *British Journal of Photography*, Dec. 9, 739-741, 757-759.

Rudd, R. G. 1950. Copying the Black-and-White Print. *Photographic Society of America Journal*, section B, June, 30-38.

Southworth, M.G. 1979. *Color Separation Techniques*. 2nd ed. Lavonia, N.Y.: Graphic Arts Publishing, 26-38.

Spencer, D.A. 1979. *D.A. Spencer's Colour Photography in Practice*. Rev. ed. by L.A. Mannheim and Viscount Hansworth. London: Focal Press, 339-354.

Sturge, John M., ed. 1977. *Neblette's Handbook of Photography and Reprography Materials, Processes and Systems*. 7th ed. New York: Van Nostrand Reinhold, 240-241.

Todd, H.N., and R.D. Zakia. 1974. *Practical Sensitometry: The Study of Tone Reproduction*. 2nd ed. Dobbs Ferry, N.Y.: Morgan & Morgan.

Horse ranching. Cypress Hills, Alberta. ca. 1914. William James Topley.
Contemporary print from glass plate negative. National Archives of Canada/PA-011480.

7 Paper Conservation Treatments as Applied to Photographs: A Review

7.1 Introduction

Because most photographs in archival and museum collections have paper supports, the physical conservation of photographic materials has taken its cues from conventional prints and drawings conservation techniques. These techniques often are modified significantly as a result of the multilayered structure of photographs and the properties of the emulsion materials. Comparatively little research has been conducted in the area of photograph conservation.

This chapter reviews basic paper conservation techniques as applied to photographs and provides a list of supplementary readings from the professional literature. Many of the techniques and treatments discussed here require a high degree of manual skill, which can be learned only through careful observation and considerable practise under the supervision of trained conservators. This is not a "how to" manual. As with any art object, individual assessment is a necessary step in determining treatment options and for that reason standardized treatments in the form of structured experiments are not included in this chapter. We expect the supervising conservator to ensure that the student obtain experience and a high degree of expertise in all treatments discussed here.

Treatments carried out during the practical portion of the study guide must involve the use of discarded materials and the results must be evaluated by the supervisor.

When a photograph is identified by a custodian or curator as requiring treatment, a condition report is written based on the thorough examination of the photograph. Using this information, a treatment proposal is formulated by the conservator, which is subject to the approval of the curator or custodian before the treatment can commence (see Chapter 11). The photograph is always photodocumented to accurately record its condition prior to treatment; when an object is particularly valuable or a treatment is potentially dangerous, it may be desirable to produce a densitometrically correct copy negative (see Chapter 6). As this is a time-consuming and expensive process, it may not be practical for all objects conserved. Photographic documentation is an essential step that may sometimes facilitate the evaluation of a completed treatment. The photodocuments not only provide a record of the treatment carried out, but also provide future generations of conservators who may work on the object with information necessary in order to conduct further treatment. A copy negative may be used to produce a surrogate that preserves the information in the unlikely event that the original is damaged or destroyed.

The first step in assessing the condition of a photograph is to correctly identify the support material, image-forming substance(s), and binding medium. Then, the condition of each layer is assessed. Signs of chemical or physical deterioration of support layers, solubility of the binding medium, and chemical alteration of the image-forming material are clearly noted on the condition report. Proposals for aqueous or solvent treatments must be preceded by spot tests, to ensure that the treatment will not cause further deterioration to the photograph. Above all, the conservator should consider each photograph a unique object that may require special treatment, regardless of how many similar objects he or she has treated in the past.

Similarly, paper conservators should never assume that a standard paper conservation treatment carried out on photographs will have a standard result. The mounting and backing of photographs can cause dimensional changes that threaten certain emulsions. Aqueous treatments carried out on albumen prints can result in increased cracking of the emulsion layer (Swan, 1981). The use of hot spatulas or tacking irons on silver gelatin prints can cause yellowing of the emulsion. For this reason, work carried out in this section of the study guide is scrutinized and supervised by a person trained both in photograph conservation and paper conservation.

Fig. 7.1: Before and after treatment photographs of a print conserved using standard paper conservation techniques.

7.2 Surface Cleaning

7.2.1 Dry Cleaning

Dry cleaning refers to the mechanical removal of surface dirt. Such treatments are restricted primarily to the mounts (secondary or tertiary support) and the non-image side or backs (referred to as the "verso"; the image side is referred to as the "recto") of photographs on paper supports. Erasers and eraser powders, such as Scum-X, can be quite effective in removing surface dirt from compact paper surfaces. Eraser powder is dropped on the surface of the mount and manipulated with the fingertips in a gentle circular motion. Excessive pressure can result in ripping or crinkling of the paper. The motion should be directed towards the edge of the print, to avoid catching the edge and creasing it. This same center-to-edge movement should be used with solid erasers as well. Dry cleaning should not be carried out on severely degraded papers or papers with delicate surface characteristics.

The emulsion of a photograph can be cleaned with a soft brush to remove dust and dirt particles. However, with certain fragile or deteriorated emulsion layers, and with degraded salted paper prints, this may result in loss of image silver and/or damage to the binding medium. Attempts to dry clean emulsions may result in an alteration of the surface gloss and in some cases removal of the emulsion itself. In the case of albumen photographs, the eraser powder may be driven into the tiny cracks inherent in this emulsion, causing further stress and deterioration. In those cases where vulnerable photographs are mounted to secondary supports, care should be taken to protect the photograph surface during dry cleaning of the support.

Because most eraser materials contain sulfur compounds, it is important to remove as much residue as possible following treatment (Pearlstein et al., 1982; Moffatt, 1981). This can be accomplished with a soft-bristle brush. Pencil notations on mounts, such as signatures and captions, should not be removed without consulting the responsible curator or custodian.

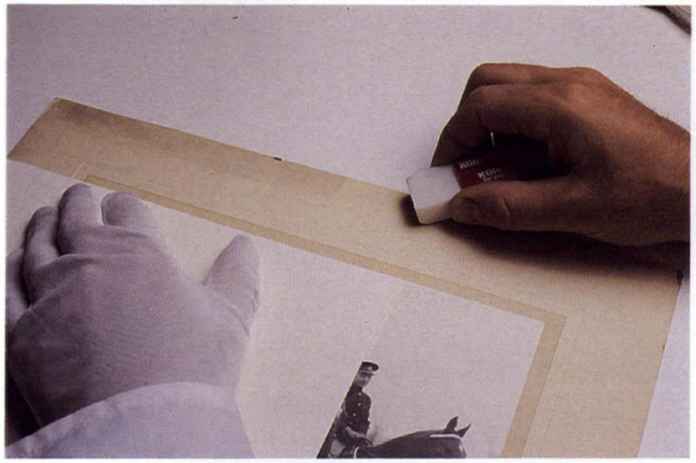


Fig. 7.2: Dry cleaning the margin of a secondary support using vinyl erasers.

7.2.2 Wet Cleaning

Aqueous Treatments

All the techniques described here can be used only on photographs that have been tested and found to be stable enough to survive aqueous treatments. Spot testing and close visual examination are the primary test methods. Chapter 10 describes various pieces of diagnostic equipment and procedures used to determine the stability of emulsions in aqueous solutions. These are destructive tests conducted on disposable materials only, the results of which can be used as guidelines and points of comparison in an attempt to determine the stability of originals to be treated.

Fig. 7.3: Cleaning stable emulsions using distilled water or solvents is accomplished by gently "rolling" lightly dampened swabs across the surface.

Under certain storage conditions (high temperature and relative humidity), gelatin emulsions can deteriorate to the point where water will easily break up the gelatin layer. Spot tests should be carried out to exclude such weakened photographs from aqueous treatments. On a discrete area of the print or negative, let a drop of water sit for a minimum of 30 seconds to one minute. Place a square of clean blotter on top of the spot. Gently blot, looking for signs of any disturbance of the emulsion layer.

As early as 1840, people were handcoloring photographs. A variety of media were used, most of which are water soluble. Do not attempt to wet clean these materials unless thorough spot testing as described above proves them to be quite stable.

If the emulsion passes the spot test, some surface dirt can be removed effectively by rolling lightly dampened cotton swabs across the surface of an emulsion. "Rolling" is the only acceptable technique as scrubbing may result in driving the dirt further into the surface and may cause mechanical damage to the emulsion. Swabs must be changed frequently.

Gelatin prints and negatives that are in very good condition but exceptionally dirty can be totally immersed in a bath of distilled water. (see Section 7.5.) The dirt can be manipulated away from the surface using a soft paint brush. Mounted photographs cannot be immersed unless they are removed from their mounts and have a water-soluble adhesive. If it is necessary to increase the penetration and solvent effect of water, ethyl alcohol (beginning with a 5% solution) can be added to the distilled water bath. Alcohol should never be used on collodio-chloride prints as it dissolves collodion. Regardless of how stable an emulsion appears during spot testing, one must always be prepared for the unexpected. Items immersed in a bath should be watched continuously for at least the first 10 minutes. Should an emulsion begin to dissolve, remove it immediately from the bath, hold it horizontally, keep it flat, and allow it to air dry. Do not attempt to blot it dry as you will lose the emulsion entirely.

A 1:1 mixture of water and ethyl alcohol can be used to remove greasy dirt and to limit the streaking on the non-emulsion side of glass plate negatives, ambrotypes, and lantern slides. This should be done carefully with cotton swabs so that no liquid reaches the emulsion side of the plate.

Non-Aqueous Treatments

Solvents can sometimes be effective in the removal of surface dirt and accretions such as a wax crayon. All solvents must be spot-tested prior to use to avoid image or binding layer alterations, or deterioration and staining of the support layer. Tide lines (stains resulting from impurities that collect at the edge of a wetted area), for example, can be very disfiguring, particularly in highlight areas. In cases where spot-testing indicates possible problems, the student should consult with the supervisor before proceeding.

We recommend Kodak Film Cleaner for the removal of greasy stains on emulsions. A stain unaffected by water may be presumed to be an oily stain. The same rolling motion with cotton swabs should be used on the emulsion surface. This technique will have little effect on water-soluble accretions. It may be wise to use the film cleaner (solvent) first on a particular stain, before proceeding to an aqueous treatment. Non-aqueous solvents evaporate quickly, do not swell the gelatin, and thus affect the gelatin less than water.

Many other solvents can be used safely on gelatin and albumen photographs. For example, wax crayon can be removed from albumen prints using a 1:1 mixture of petroleum spirits and acetone. Because most solvents are toxic, these

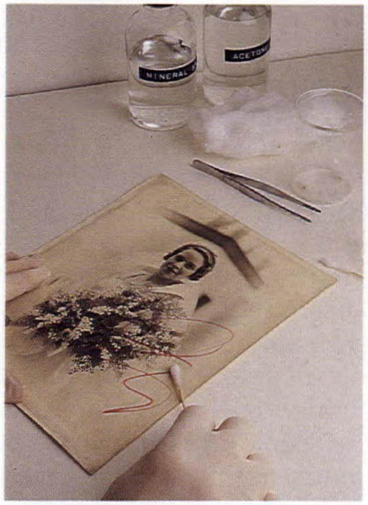


Fig. 7.4: Removing wax crayon from the emulsion of a photographic print.

treatments should be carried out under a fumehood. Also, safety glasses, lab coats, and the appropriate plastic gloves should be worn when using any of these solvents.

7.3 Removing Photographs from Mounts

A photograph should be removed from its mount only when the mount is of sufficiently poor quality that it is contributing to the degradation of the picture. It is usually advisable to remove photographs that have been slipped into album pages (as in the case of *carte-de-visite* and cabinet card photographs) for display purposes, when excessive damage would result from displaying the entire album. Certain mounts, such as those used on *cartes-de-visite*, cabinet cards, and stereographs, should not be removed, because they are an intrinsic part of the image and often contain information that is essential to the dating and identification of the image, photographer, and sitter or subject. However, if the mount is of little intrinsic value and is causing the photograph to deteriorate, it should be removed.

The dismounting of photographs is risky, and many factors must be considered before deciding to do so. The mount itself, with inscriptions or signatures, may contain archival evidence or information essential to the identification or authentication of certain photographs. Many mounts tell the history of the picture, and the loss caused by removal might be greater than the potential for damage to the photograph from physical contact with poor quality materials. For these reasons, the curator or custodian should be consulted and approve the treatment.

The migration of acids from deteriorating paper mounting boards can break down the paper base of the photograph, making it brittle and discolored. Residual sulfur compounds from the pulping process and atmospheric pollution eventually can result in sulfiding of the image silver. A degraded mount, if improperly handled, can easily fracture, breaking off sections of the photograph with it.

Early mounting adhesives included starch paste, gum arabic and starch, arrowroot and gelatin, starch and gelatin, starch and dextrin, and gum arabic and dextrin adhesives, all of which are water soluble. One of the earliest dry-mount adhesives for photographs (non-aqueous) was a solution of shellac in alcohol (Grigsby, 1977).

Colored mounts must be tested prior to treatment, to ensure that the dyes will not bleed into the photograph. Sometimes mounts carry water-soluble inscriptions that bleed into the photograph. Also, mounted prints could contain water-soluble inscriptions on their verso and bleed during mount removal, in which case, mount removal must involve as little moisture as possible. Handcoloring on the photograph will also contribute to the decision of how to remove a mount. As most handcoloring media are water soluble, a minimal amount of moisture should be used.

Photographs with water-soluble components or that have been severely damaged mechanically and have been mounted with water-soluble adhesives can be removed effectively with little risk by humidification using a Gore-Tex membrane. The Gore-Tex membrane, an aerated Teflon laminated to a 100% polyester non-woven felt, is laid over a stack of damp blotters. Due to the low absorbency and the small pores of the Gore-Tex and the high surface tension of liquid water, only the water vapour penetrates. The mounted photograph is laid onto the Gore-Tex and the entire assembly is covered with a light-weight felt blanket. The procedure may require several hours before the adhesive softens, depending on the thickness and type of mount and the type of adhesive used (Keyes, 1988).

Once the adhesive layer has been softened and starts to release, the print is laid face down on a clean blotter and the mount is lifted and peeled off. When peeling a mount from a degraded photograph, exercise caution so as not to tear the photographic paper support. The photograph must be kept flat during the process to ensure that the emulsion is not cracked or damaged in any way. In the case of very thick mount boards, it is sometimes necessary to thin the backing using scalpels and spatulas, prior to humidification.

Gelatin photographs that are in very good condition can be completely immersed in water and floated off their mounts. When gelatin adhesives have been used to mount the photograph, warm water will be required to soften it.

Adhesive that remains on the back of photographs after dismounting can be removed by blotting it up with pieces of clean blotter or by lifting it off with a firm-bristle brush. If the photographic paper is in good condition and is fairly heavy, the adhesive can be scraped off gently with a spatula.

Fig. 7.5: The mounted photograph is placed on the Gore-Tex membrane with damp blotters below and then covered with a felt blanket.

If there is the possibility of water-soluble inscriptions on the verso of the print or if the stability of the emulsion is questionable, dry removal of the mount board down to its final paper layer will be necessary. This involves the careful use of a sharp scalpel or a fine spatula to slowly cut away layers of the board.

Once the mount is thinned to the point where the adhesive layer is exposed, small quantities of solvent or poultices of methyl cellulose can be applied locally, with care taken to minimize the

Fig. 7.6: Paring down a degraded mount board to its final paper layer.

Fig. 7.7: A methyl cellulose poultice minimizes the penetration of moisture into the photographic print while softening the adhesive.

penetration of the liquid into the photograph. A highly acidic mount can deteriorate photographic paper in direct contact with it and, therefore, caution is required so as not to "skin" (remove paper fibre from) the photograph. This is a very time-consuming procedure and one necessitating full control, as one slip of the scalpel could severely damage the print. Such a treatment should be carried out only under constant and direct supervision.

Methyl cellulose poultices can be used in those cases where free-flowing liquids must be avoided. They are a valuable tool in the removal of residual adhesive and mounts. (see Section 7.4 for further uses of poultices.) If any questions exist about the stability of an object in aqueous solutions, poultices and the use of Gore-Tex membranes provide an alternative.

Water-based adhesives that are not easily dissolved by water alone can sometimes be broken down with the aid of enzymes. Starch-specific enzymes will break down starch adhesives. However, protein-specific enzymes cannot be used on photographs for proteinaceous adhesives, such as animal-skin glues, because the enzyme will attack the gelatin layer as well as the adhesive layer. Enzymes can be applied by a variety of methods, including brushing on, immersion, and in poultices. The preparation of enzymes must follow careful directions, as the activity of the solution is dependent on specific temperature and pH requirements (DeSantis, 1983; Burgess, 1987).

Solvents must be used to remove dry-mounted (i.e., heat-mounted) photographs from their supports. Shellac-based adhesives are soluble in 100% ethanol. (Isopropyl or denatured alcohols contain petroleum byproducts, which will remain on the print.) Immersion may be necessary or local applications may suffice. In either case, the photograph must be tested to determine its condition first. As a last resort, modern dry-mounting tissues can be removed by immersion in acetone.

In extreme cases where albumen and other non-baryta prints must be removed from mounts containing soluble inscriptions, and the mounts are to be kept, a solution of water and alcohol can be applied to the emulsion side of the print, keeping within the edges. It is essential that the print be in very good condition as the solution is brushed on with a soft brush. The solution will quickly penetrate the emulsion to the adhesive layer and, once softened, the print can be removed. Because only the photograph is wetted in the process, it is weaker and will be damaged if force is used. This procedure should be used only as a last resort and under the direction of a trained conservator.

7.4 Removal of Tapes and Non-Aqueous Adhesives

In the past, custodians of collections, such as librarians and archivists, have liberally used ordinary pressure-sensitive adhesive tapes to prevent the loss of detached pieces of ripped or torn documents and photographs. Custodians and curators are now more aware of the deleterious long-term effects of such materials and the use of cellophane pressure-sensitive tapes and other damaging materials, such as rubber cement, has greatly diminished coupled with the availability of safer pressure-sensitive "archival" tapes and adhesives.

The removal of damaging tapes and adhesives presents difficult challenges to the conservator. Such materials deteriorate rapidly, often destroying the document they were meant to repair. Many adhesive tapes become highly acidic over time, causing staining and destruction of paper fibres. In those images where the adhesives have reacted with photographic emulsions, removal of the tape invariably results in the loss of those emulsion areas. With care, such damage can be minimized.

A 1:1 mixture of toluene and hexane (used under a fumehood and wearing safety glasses, gloves, apron, etc.) has been found to be a very effective solvent for tape and adhesive removal. Others, such as acetone and trichloroethylene, are also used extensively. After spot testing, an excess of solvent is swabbed onto the tape, loosening the adhesive around the edges. A corner of the tape carrier is then lifted and a solvent-laden swab is gently rotated under the tape, while the tape is gradually

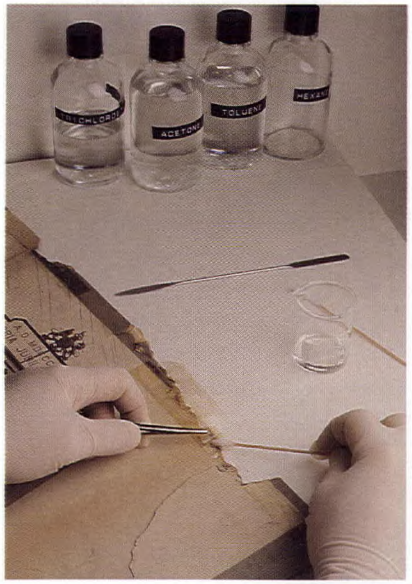


Fig. 7.8: The removal of degraded pressure-sensitive tape from a photograph.

lifted with tweezers. This must be done slowly to allow the solvent time to penetrate the adhesive.

Once the tape carrier has been removed, a layer of adhesive will inevitably remain. The area can then be swabbed with solvent, and the adhesive (which will have a jelly-like consistency) can gently be pushed off the print surface with a micro-spatula. If the print surface is damaged, the area should be swabbed with solvent and pieces of clean blotting paper can be used to gently blot up the remaining adhesive.

Poultices can also be used effectively for the removal of adhesives. Any non-colored, stable, highly absorbent material can be used as a poultice, including Fuller's Earth, fumed silica, cellulose powders, etc. The absorbent component is mixed with the solvent to a thick paste-like consistency and applied to the adhesive-stained area. The solvent solubilizes the adhesive and as it dries out, the adhesive is drawn into the poultice. Once it is completely dry, the poultice can be easily lifted off and the residue brushed or swabbed from the surface. This procedure can be very effective when used in conjunction with a suction table. Heavy residues can first be removed using poultices and then stains reduced as described below (Smith et al., 1984).

The tape-removal procedure must be done carefully to avoid driving adhesive further into the paper fibres and potentially causing tide lines. A cold suction table, if available, may be effective for adhesive stain removal from non-emulsion-type photographs such as salt prints, platinotypes, etc. Suction tables depend on capillary action to draw liquids through the paper fibres into blotting paper below thus eliminating the possibility of tide line formation. For prints that have been virtually covered with pressure-sensitive tape, immersion in a solvent bath may be required. Once the adhesive has been dissolved and the tape removed, the print should be thoroughly rinsed in clean solvent to remove residual adhesive. This treatment should be reserved for extreme cases only.

7.5 Washing Prints and Mounts

Washing Prints

When a considerable amount of grime and accretions is present on the surface of prints, and when the paper support is discolored, aqueous washing may be required. The photograph must be in good condition, however, and all emulsions should be spot-tested prior to immersion. In any event, immersion time should be kept to a minimum.

Immersion should be used only with undeteriorated silver gelatin materials. According to recent tests, immersion of albumen photographs can result in an increased cracking of the emulsion surface (Swan, 1981). Certain historical processes, such as starch prints (rarely found in collections) and badly deteriorated silver gelatin prints and negatives are extremely fragile in aqueous solutions. Also, salted paper prints can lose density when washed by immersion. In the latter case, float-washing or washing on a paper suction table is preferable. Also, as mentioned earlier in the chapter, handcolored materials cannot generally be washed due to the solubility of most coloring media.

For immersion washing, only distilled or deionized water should be used. A piece of polyester webbing must support the photograph as it is immersed in or removed from the water. Surface dirt can be brushed gently from the surface, using a soft, wide brush.

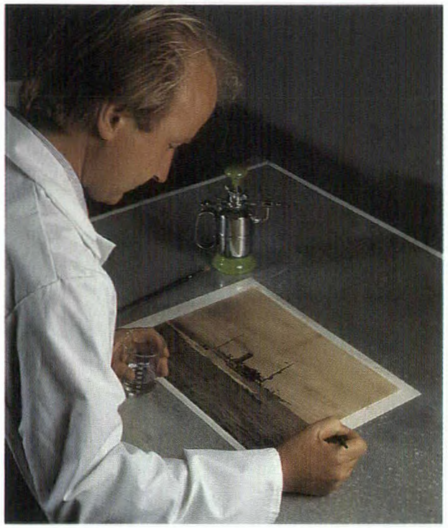


Fig. 7.9: Washing a platinum print on a paper suction table.

When the paper support layer itself carries the stains or dirt, photographs may be float-washed to draw out some of the staining through the back surface. Take care not to sink the document. This is a useful technique for salted paper prints, platinum photographs and any other non-emulsion-type (single layer) photographs. Paper suction tables are also extremely valuable tools for these types of materials. Non-emulsion-type prints can be washed safely without loss of image particles.

Sturdy, washed prints should be placed face down onto fibreglass screens with a Reemay interlayer and air dried. Fragile prints should be dried slowly and evenly (in a humidity chamber), face up. Once water is no longer evident on the surface, gently lay a piece of polyester webbing across the surface to minimize curling of the print.

Washing Mounts

Photographic mounts often contain valuable information about the image, its photographer, date, and provenance. As destruction of the mount would mean the loss of this information, the conservator, after consultation with the curator, may decide to treat the mount board or support. If the mounting material represents a significant threat to the photograph, or cannot be treated, it can be removed and stored separately from the photograph.

The mount must be spot-tested before treatment to determine whether it contains water-soluble dyes and ink notations. Gilding on mount edges and decorative effects can be lost during aqueous treatments. Most early mounting boards were made from materials that are highly acidic. The boards themselves often become brittle. If all components are stable enough to withstand aqueous treatment, the mount board can be subjected to a standard water wash, followed by deacidification, if it remains highly acidic. Deteriorated wood pulp mounts can turn to mush during washing, necessitating close monitoring of the process. Valuable mounts that have become stained may benefit from bleaching. Many handwritten ink notations are extremely sensitive to bleaches and must be thoroughly tested. The supervisor should approve use of the bleaching treatment and should direct the procedure. Stabilized hydrogen peroxide and sodium borohydride bleaches are generally recommended over others such as chlorine dioxide. The work must be closely monitored for the evolution of hydrogen gas bubbles which can potentially cause mechanical damage to badly degraded papers and boards. Thorough spot testing is required prior to treatment.

An alternative solution is to remove the top and bottom layers of the mount board, using a sharp, thin spatula or by delamination in water. These two layers are then remounted, using starch paste on an appropriate thickness of new acid-free museum mounting board.

Repairs to mount boards can be made by standard methods, using Japanese tissue and wheat starch paste or carboxy methyl cellulose, followed by in-painting to compensate for losses if necessary.

Extremely deteriorated mounts or boards carrying highly soluble ink printing or inscriptions may be deacidified with a non-aqueous solution (WEI T'O). They may then be stored in close proximity to, but not in direct contact with, the photograph. A special mat can be constructed to hold both the mount and the photograph in such a way that they are not in direct contact.

Stable mounts with considerable surface dirt can be cleaned without dismounting the photograph by first dry cleaning with a vinyl eraser, followed by the application of methyl cellulose poultices. This should be restricted to strong papers and boards with compact surfaces. The water from the poultice is allowed to penetrate the surface of the paper, dissolving dirt and stains. It is then removed with a lightly dampened sponge. You must work quickly to avoid moisture penetrating too far into the board, which can cause warping and delamination (Kennedy, 1988).

7.6 Repairing Tears

Traditional paper conservation techniques can be successfully employed to repair physical damage to the paper support of a photographic print. Thin Japanese tissue is used to bridge tears and ruptures and adhered with sodium carboxymethylcellulose or wheat starch paste. The following tools and materials should be assembled on a clean work surface: Japanese tissue, adhesive, a paste brush, a straightedge, weights, small squares of polyester webbing, blotter squares, a tacking iron, a small watercolor brush, distilled water, and silicone release paper.

Prior to any repair work, thoroughly spot test the materials involved to determine whether the adhesives and repair treatments are safe to use. Evaluate the strength of both the support and emulsion layers and note any distortion or warping of the break edges. Dirty break edges can result in repairs being quite visible; this should be anticipated and discussed with the responsible curator. Some conservators consider the removal of some of the paper fibres from a dirty break edge an unethical treatment; as a rule, we do not do it in this lab.

Because of uneven expansion and contraction of the paper fibres, old tear edges may be difficult to realign. It sometimes helps to manipulate the dry edges, applying small mends gradually and checking the alignment as each join dries. It may be necessary to use weights to hold the pieces in alignment while mends are applied and while they dry. The paper can be expanded locally, using distilled water and weighting it while it dries, to manipulate the paper into alignment. However, excessive stress must be avoided. In general, successful realignment of torn paper fibres requires considerable practise.

The Japanese tissue to be used for repairs is divided into thin strips, the dimensions of which will depend on the size of the tear to be repaired. To produce a water cut with a frilly edge (which provides an abundance of free fibres to adhere to the print, and which eliminates the ridge caused by mends made with straight-cut edges), place a straightedge along the edge of the paper, run a wet brush along the edge, and tear the paper along this water line. The Japanese tissue should be light-weight, yet strong, and for aesthetic reasons, as close to the original in color as possible. Repairing tears on very heavy photographic papers will require the use of a relatively heavy repair tissue. Heavy photographic papers may also require the application of paste directly to the break edges to maximize the strength of the repair. Aqueous adhesives should be reasonably dry as water flooding into the paper can cause tide lines and excessive swelling of the repair area.

First align the torn edges, and hold them in place with weights. Apply paste to the repair tissue, brushing from the center to the outside edge, so that the edge fibres extend out. Lay the tissue onto the tear (always on the photograph verso), and with a lightly pasted brush, smooth the edges out to ensure maximum adhesion.

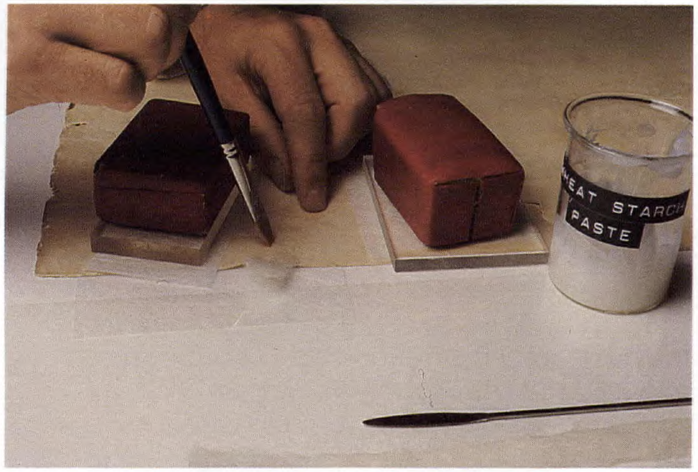


Fig. 7.10: Repair tissue applied to aligned break edges.

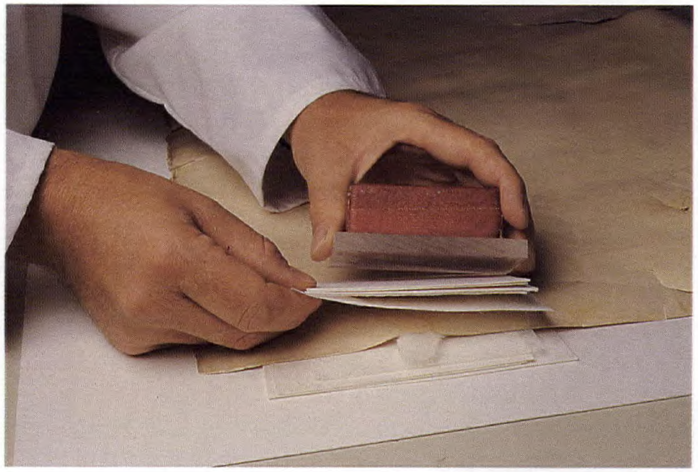


Fig. 7.11: The repair is sandwiched between polyester webbing and blotters and weighted until dry.

Sandwich the repair between two pieces of polyester webbing and several layers of blotting paper and cover them with a weighted piece of Plexiglas. Remove the repaired piece only when it is completely dry. Change the blotters frequently for the first few minutes to avoid cockling (puckering).

Some photographs are torn in such a way that the tear edges overlap. Paste may be applied directly to the break edges, only after the emulsion has been tested for solubility. In most cases, repair tissue will also be required on the verso.

In the presence of water-soluble components, a solvent-activated or heat-activated adhesive may be required. The photograph first must be tested for the effects of both solvent and heat. Because heat can cause discoloration of degraded emulsions, solvent activated adhesives are generally preferred. The mending procedure is similar to that described above. The thin Japanese tissue is first coated with the appropriate adhesive, allowed to dry, and then divided into strips. The tear is aligned, the strip laid in place, and the appropriate activator applied. For these purposes, adhesives such as Beva 371 (for heavy baryta papers) or Lascaux 360HV, among others, may be considered (Down, 1988; Volent, 1989). Considerable research is currently being conducted in this area, particularly concerning the reversibility and long-term stability of these adhesives.

7.7 Filling and Compensating for Losses

Damage to photographs often takes the form of holes and losses, particularly along the edges. It is more difficult to repair photographs that have an emulsion, because the refractive index and texture of albumen and silver gelatin emulsions, for example, are difficult to simulate. Choose a paper that is close to the original in weight, texture, and color.

Once the appropriate paper has been chosen, the outline of the hole to be filled is transferred to the repair paper, using a pin tool. The edge of the fill paper is chamfered (bevelled) to approximately 1/8" outside the hole demarcation, using a sharp scalpel. The chamfering is done on a piece of glass. Depending on the size of the fill, it may be advisable to tone the fill (with acrylic, watercolors, or dry pigments) before fixing it in place, to ensure an even color. (Traces of adhesive that remain on the fill will affect the paper's ability to receive retouching paints.) The fill is pasted with adhesive along the chamfered edge and set into place. It is burnished to ensure good contact. The repaired piece is sandwiched between two squares of polyester webbing, followed by squares of blotting paper, all of which are weighted down until completely dry, to avoid cockling or warping. Blotters should be changed frequently in the first few minutes to avoid cockling during drying. Once secured and dried, the fill can then be coated with gelatin or other coatings, if necessary, to attempt to match the refractive index of the emulsion layer.

In-fills can be made using Japanese tissue. Several pieces are pasted together to match the thickness of the original and scribed along the top surface to match the hole to be filled. The bottom layer of tissue is left approximately 1/8" larger, in order to overlap the original and hold the fill in place.

Filling losses successfully requires manual skill and experience. Certain techniques may raise ethical issues, such as the removal of original material from a fill area (not executed in this lab). This and all treatment steps must be discussed with the curator or custodian prior to execution under the direct supervision of an experienced paper conservator.

Fig. 7.12: A photograph (left) prior to and (right) following placement of infills.

7.8 Flattening Prints and Negatives

Most photographs on paper react noticeably to the presence or absence of moisture in the air. Under extremely dry conditions, emulsions shrink slightly, forcing the print to curl inward. Albumen photographs, particularly, which have a very thin paper support layer, curl when stored in dry conditions. To observe this, place an albumen photograph in a desiccation chamber containing a saturated solution of lithium chloride, which provides an RH of approximately 12%. The print will very quickly begin to curl. Next, place the print into a humidity chamber with an RH of 100%; it will flatten completely in a few minutes' time.

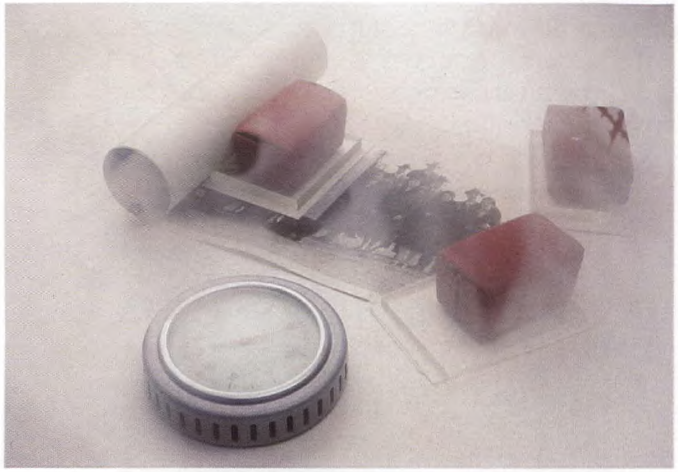


Fig. 7.13: A rolled panorama in a humidity chamber.

To mechanically flatten prints, introduce some moisture into the emulsion, by either placing the print into a humidity chamber until it "relaxes," or by misting the emulsion and verso lightly with distilled water from a fine atomizer. If the emulsion is actually wet, let it air dry for a short time before placing it between blotters. Place a piece of fine polyester webbing between the emulsion and the blotter. This is particularly important with silver gelatin prints as the moistened gelatin will be soft and could stick to the blotter. The stack of blotters containing the photograph should then be covered with a sheet of plate glass and moderate weight placed on top. It is essential that the weight be distributed evenly. It is essential, also, to change the blotters several times in the first few minutes to avoid cockling, if the print was quite damp when placed in the blotters. It is important to place the object between blotters before it starts to distort as would occur during air-drying (Vitale, 1989). If not completely dry when removed from the blotters, the print will likely curl again. One must use only photographic blotters, because standard blotting papers have a slight texture, which can transfer to the emulsion of the prints (especially silver gelatin prints) under pressure.

Prints and negatives that have been stored in rolls for an extended period can be difficult to flatten. Furthermore, you should proceed with greater caution in these cases, because the film base and/or emulsion layer may have become brittle and could crack in the process. These rolled materials should be placed in a humidity chamber until they can be easily manipulated and unrolled to a flat position.

This should be a gradual process, unrolling only a small section at a time as it relaxes. An ultrasonic humidifier used in a sealed chamber works very well, providing that the object is protected from water condensing on the surface.

Due to their large size, they may require several blotters to completely cover them. Polyester webbing should first be placed between the emulsion and the blotter. It is important to butt the blotters against each other, to avoid leaving ridges on the emulsion surface. Several layers of blotters should be built up and the assembly weighted under glass for several days, until thoroughly dry.

Immediately following removal from the blotters, each negative or print should be placed into a Mylar sleeve sealed along two or three sides or an acid-free paper envelope that is only slightly larger than the object. The storage enclosure must be strong enough to counteract the curling tendency of the negative or print. Once it is properly enclosed, it may be placed in a file folder or negative storage box and stored vertically. Oversized material should be stored horizontally.

Cockled or creased objects that are extremely sensitive to moisture can be successfully flattened by exposing them to water vapour to humidify

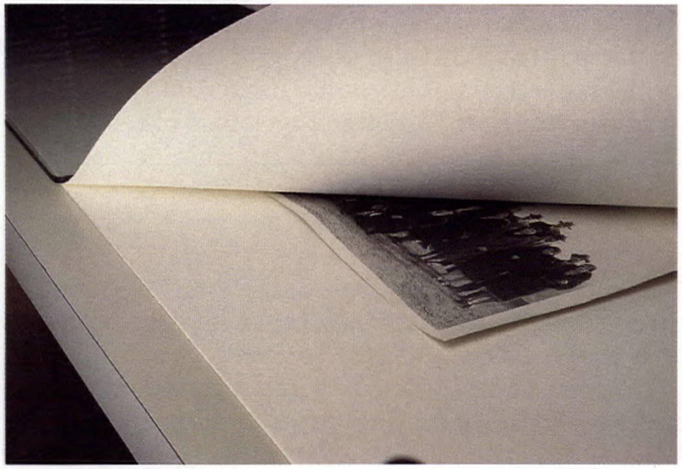


Fig. 7.14: Panorama placed between blotters and then weighted until dry. Blotters are butted against each other rather than overlapped to avoid creating a ridge on the photograph.

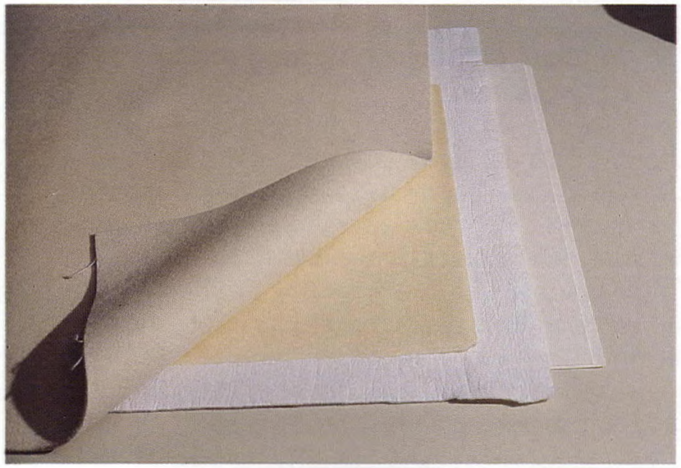


Fig.7.15: Felt blanket, photograph lying face down on Gore-Tex membrane and blotter.

them. This can be accomplished using a Gore-Tex membrane as described in Section 7.3 (dismounting of photographs) so that only water vapour penetrates. By covering lightly dampened blotters with a piece of Gore-Tex membrane and then placing the object on top, followed by covering the entire assembly with a piece of lightweight felt blanket, the object can be gently humidified (Keyes, 1988). The amount of time required will depend on the object itself (i.e., the thickness of the support and the severity of the creases or cockling). It is a relatively slow process, possibly taking a few hours, and should not be rushed. Once relaxed, the object should be removed and placed immediately between lightly weighted blotters for several days or more.

7.9 Application of New Backing or Support and Encapsulation

Photographs that have sustained considerable damage to their paper support layer will require a new backing. Poor environmental storage conditions may have severely weakened the photographic paper. Careless handling of photographs can result in tears that weaken the photograph to the point that a new backing is required. Prints that were carelessly removed from mounts may have had their paper support layer "skinned." Photographs mounted on poor-quality boards are subject to deterioration from migrating acids and may require new acid-free mounts. Any of these situations may call for the application of a new support or backing layer.

Albumen photographs were traditionally produced on very thin paper; curling was an inherent problem at the time they were produced as well as now. This required that most albumen prints be mounted and, indeed, most found in collections are in that state. While an unmounted albumen photograph may be encapsulated, or stored in a sturdy Mylar sleeve, the application of a paper backing or support may be the preferred solution, depending on the collection's storage conditions and research use.

Mounting papers for photographs should match the thickness of the original. If the support paper is too thin, there will be a tendency for the print to curl inward. If the paper is too thick, there will be a tendency for it to curl in the opposite direction. Where a choice must be made, the heavier paper is preferred. Traditionally, photographic papers were of the highest possible quality, either 100% rag writing papers or high alpha-cellulose fibre and lignin-free pulp papers. Many Japanese tissues are ideally suited for use as a secondary support, because they are made from pure, long fibres that are substantially lignin-free and, generally, of neutral pH. Because of these long fibres, they are strong papers. Additionally, Japanese tissue comes in a variety of weights and natural colors. From the standpoint of aesthetics, it is important to match the color of the mounting paper to the color of the photographic paper. Many handmade non-buffered 100% rag papers are available and may be more suitable for prints with heavy paper supports.

Approach the application of a new backing or support with caution. Although it may be to the ultimate good of the piece, the procedure can create stresses on the original and can result in slight dimensional changes that may impair the image's strength and appearance significantly. Albumen photographs have been observed to crack to a greater degree following wetting, washing, or aqueous backing treatments, particularly when they are backed and dried on a rigid surface, such as a table top (Swan, 1981). Tears and losses should be repaired prior to lining using standard repair techniques as outlined in Section 7.6, so that they won't open up during the drying process.

Aqueous Mounting Techniques

The adhesives most highly recommended for their stability and reversibility are sodium carboxymethylcellulose and wheat starch paste.

Aqueous adhesives can be used to secure the new support layer to the photograph using three common methods, the choice depending on the kind of photograph involved and its original condition.

1. The simplest, yet preferred, procedure for most relatively stable photographs is widely used by paper conservators. A secondary support is pasted up on a piece of Mylar, or the photograph is pasted up while lying face down on a piece of silicone release paper. The lining is placed in contact with the verso of the photograph and gently rolled to ensure adhesion. The Mylar and silicone release paper are then removed and the assembly is sandwiched between two pieces of polyester webbing. The lined photograph is then allowed to partially air dry, followed by complete drying between blotters under evenly weighted plate glass. The blotters should be changed every few minutes to ensure against cockling if the object was quite damp just prior to being placed in the blotters. The object should be left between blotters for a minimum of three days and much longer if possible. The excess tissue is then trimmed to the edge of the print.

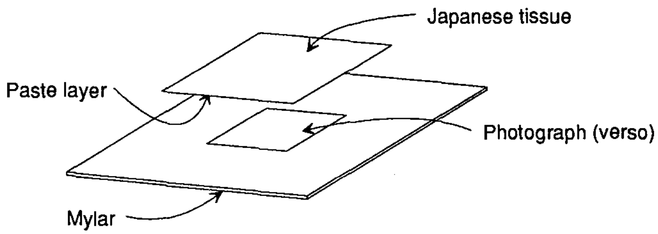


Fig. 7.16: Pasted out lining paper adhered to verso of the print.

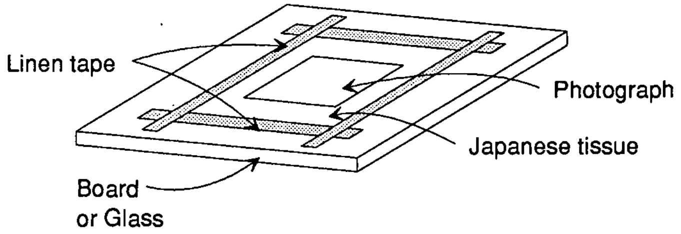


Fig. 7.17: The lining paper is wetted and stretched onto a smooth board, pasted out, and the photograph laid on top.

2. The lining paper is thoroughly moistened until maximum expansion of the paper fibres has occurred. It is then stretched onto a board and taped securely along all four edges. As the paper dries, it shrinks, creating tension across the surface; the degree of expansion when the adhesive is applied is thus minimized. The dimensions of the print to be backed are marked off and adhesive is applied to the stretched backing paper. The print is then lightly misted on the front and back allowing the photograph to swell slightly and relax.

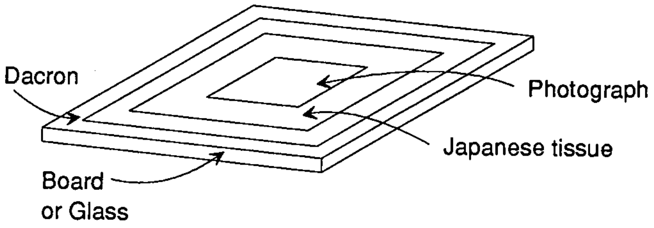


Fig. 7.18: Dacron is pasted to a smooth surface, the lining paper pasted to the Dacron, the lining paper pasted out, and the photograph laid on top.

The print is then laid down onto the pasted lining paper and covered with a piece of polyester webbing. The surface is gently rolled with a clean rubber roller, working from the center to the outside. The polyester webbing is taken off, and any adhesive along the edges is removed to avoid uneven drying. The entire assembly is left to air dry for at least 24 hours, preferably longer. To slow down and promote even drying, the surface is covered with a piece of polyester webbing followed by a piece of Mylar. While still attached to the board, any necessary retouching is done. The paper is then carefully cut from the board and trimmed to the edge of the print. This procedure works well for objects on extremely heavy papers, which have a tendency to curl.

3. The third procedure begins by pasting a piece of polyester cloth (Dacron) to a smooth flat surface, such as a table top or piece of glass. The lining paper is evenly wetted and "pasted" to the Dacron. Paste is applied evenly to the recto surface of the lining paper, to prepare it to receive the photograph. The print is lightly misted on both front and back, then laid face up on the lining paper. Polyester webbing is laid on top of the photograph's emulsion surface. The entire assembly is gently rolled, starting at the center and rolling outward to the edges, to ensure maximum adhesion. The polyester webbing and excess adhesive around the edges are removed. The assembly is left to air dry.

   Once dry, the Dacron is then lifted around the perimeter. The assembly is released from the table top by being lifted gently from each of the four corners, at an equal rate and angle. Once it is removed from the table top, the assembly is turned over and the Dacron peeled from the lining paper.

   Dacron is used in this procedure because it does not firmly bond to the lining paper and thus can be easily peeled from both the table and the lining. The final step in this procedure involves trimming the excess lining tissue to the edge of the photograph.

Non-Aqueous Adhesives

Photographs that are unstable in aqueous solutions or that carry water-soluble inscriptions can be attached to a secondary support using a non-aqueous adhesive. Either solvent-activated or heat-activated material can be used, depending on the requirements of the piece. Heat should be used only after testing the photograph for its response. Local applications of heat can cause yellowing of certain gelatin materials. If used in a carefully controlled manner, solvent-activated material can be used successfully, but only after the photograph has been initially spot-tested for potential reactions. Backing papers coated with adhesives such as Beva 371 or Lascaux 360 HV, among others, can be used effectively as support materials. Fine Japanese tissue, coated with the adhesive and allowed to dry and then activated to attach the photograph to the backing paper, can facilitate the process, providing a minimal penetration of the adhesive into the photographic paper. It will also facilitate removal in the future should it be necessary. The adhesive should never be applied to the photograph itself.

Encapsulation

Encapsulation refers to the sealing of a print or negative between two pieces of polyester sheeting. Dupont Mylar Type D is recommended, as it has no slipping agents or antistatic coatings that could degrade over time potentially damaging the photograph. Prints that have suffered badly from physical abuse but are required for research purposes or are in pieces and cannot be repaired or lined with either aqueous or non-aqueous adhesives can be adequately protected in this manner. The object is sandwiched between two pieces of Mylar which is cut at least 1" larger than the photograph on all four sides. The edges are sealed using either an ultrasonic welder, a heat welder, or by double-sided adhesive tape (Figure 7.19). Ultrasonic and heat welding are preferred to avoid the use of tapes, particularly if the object is stored or displayed vertically. Gravity can cause the print to settle down inside the sandwich, potentially resting on the tape layer. 3M double-sided tape, No. 415, $^1/_4$" wide is considered relatively stable and is widely used. Encapsulation should not be carried out on objects with fragile, flaking emulsions or on objects overpainted with chalks, pastels or charcoal. Polyester sheeting can hold static electric charges, which can attract image particles and loose emulsion layers, pulling them from their supports.

When encapsulating a photograph or an album page, for example, if a margin is maintained on one side, outside of the encapsulated area, it can be bound into a volume using a post binding. This margin or extension on one side of the encapsulated object is perforated to accommodate the posts. This style of binding allows individual pages to be removed for research or display purposes while providing considerable protection.

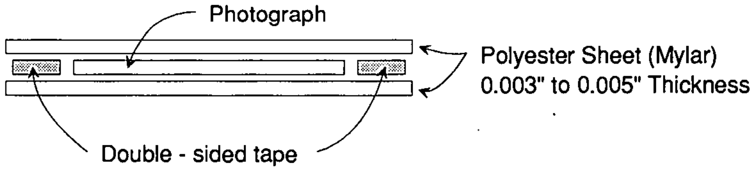


Fig. 7.19: The photograph is sandwiched between two pieces of uncoated polyester (Mylar), which is sealed along the edges.

7.10 Handcolored Photographs

Fifteen months after Louis Daguerre patented his daguerreotype process in 1839, Johann Baptist Isenring exhibited handcolored daguerreotypes in Augsburg, Germany (Eder, 1945). By March 1842, the first U.S. patent on coloring daguerreotypes was issued to Benjamin R. Stevens and Lamuel Morse (U.S. Patent No. 2522) (Rinhart and Rinhart, 1975). This desire to color photographs can be regarded as a continuation of the portrait and miniature tradition of the 18th and 19th centuries. The tradition of painting uncolored images is very old, beginning with handcolored woodcuts in the 14th century, continuing into the 19th century with etchings, engravings, etc. (Dobrusskin, 1989). It was intended, in many cases, to imitate portrait painting and in other cases to simply improve on nature as is evidenced by the quantity of gold jewellery painted onto female sitters' images and by the bright colors often used.

The handcoloring and painting of photographs, up until color photography reached the amateur market in the 1940s and 1950s, was a widely developed art. Where intended to disguise the photograph, they are referred to as "painted" or "over-painted." Photographic images that are lightly enhanced are referred to as "tinted" or "handcolored". A variety of techniques and materials have been employed over the years, all of which affect the treatment that these objects will receive.

The first task is to identify the heavily painted or overpainted image as being a photograph. In many cases the photographic image may have faded, leaving only the paint layer; in other cases, the photographic image may have been totally obscured by the paint layer.

A thorough examination is required, facilitated by the use of a magnifying device such as a 10 times lupe or a stereomicroscope. Using this device to examine areas of fine detail (e.g., lace collars, jewellery, eyes, etc.), one may detect some of the photographic image that was left unpainted in an attempt to maintain the detail. If this fails to produce positive results, a number of scientific analytical methods are available to detect the presence of photographic image-forming materials and binders. Some procedures are destructive to the image (e.g., cross-section analysis, transmission electron microscopy), as they require material sampling and therefore are not applicable to historically valuable materials. Radioisotope-Excited X-ray Energy Spectrometry (REXES) is a non-destructive test method that detects elements on the surface of the objects. The object is exposed to a radioactive source to obtain X-ray fluorescence of the elements which is then detected and individual elements identified according to the amount of energy emitted. This procedure works well for overpainted silver images unless the pigments in the paint layer contain heavy metals such as mercury and lead, which absorb the X-rays emitted by the silver. The presence of cadmium also obscures the detection of silver (Corbeil, 1989).

Fourier Transform Infra-red Spectrometry (FTIR) has also been used with some success to determine the material makeup of unknown photographic samples. Atomic bonds absorb infra-red radiation at different frequencies; the percentage of radiation absorbed at each frequency is measured; and the spectrum obtained permits characterization of the chemical nature of the object under examination. Traditional infra-red spectrometry required material sampling (i.e., destruction of the object) (Perron, 1989). Now, used in conjunction with an infra-red microscope, the infra-red spectra is obtained through diffuse reflectance, eliminating the need for sampling. REXES and FTIR analyses require the use of sophisticated equipment not available at the National Archives of Canada and is therefore not routinely done.

Spot tests (some of which are destructive), which have been described in Chapter 5, assist in the identification of a variety of photographic processes. Again, destructive tests cannot be used on original materials.

The nature of the underlying photograph, the degree of overpainting, the solubility of the paint layer, and the general condition of the object must all be carefully considered before attempting to devise a treatment for painted images. In the case of extremely fragile paint and photographic image layers, as found in handcolored daguerreotypes, no treatment should be attempted. In other cases, photographs should be referred to other more appropriate areas of expertise. For example, an oil paintings conservator may be consulted to treat objects that have been heavily overpainted with oil colors. Solar prints, also known as Crayon Enlargements, may require the expertise of a conservator of fine art on paper, as they are often drawn over with charcoal or pastel, both very fragile media.

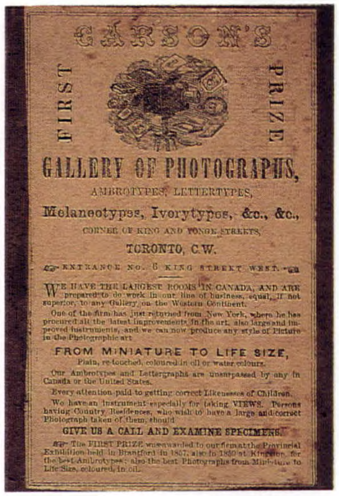
The treatment of handcolored photographs, as with all photographs, begins with a thorough examination and a condition report. As indicated above, experts from other areas of conservation should be consulted if any questions exist regarding the nature and stability of the materials. Developing treatment proposals in such cases should be a collaborative effort as should the treatment itself, if required.

Generally, treatment approaches fall into three broad groupings, depending on the nature of the material:

1. Handcolored or tinted silver gelatin and albumen prints, for the most part, can be treated as any other non-colored gelatin or albumen prints, providing the colors are stable in moisture and solvents. If unstable, they can be treated as any gelatin or albumen print that is sensitive to moisture.
2. Salted paper or platinum prints, or any other non-emulsion type print that is overpainted with watercolor, gouache, charcoal, pastel, etc., should be treated as other fine art on paper such as watercolors, prints, and drawings. This means that a fine art paper conservator is required at least at the examination stage.
3. The third major group includes images that have been heavily overpainted with oil paint. For these, an oil paintings conservator should be consulted and be responsible for any treatment of the paint layer.

Fig. 7.20: Handcolored black-and-white silver gelatin print (photographer, P. Horsdal, 1928).

Fig. 7.21: Solar print overpainted with watercolor and crayon (Portrait of Unknown Woman. Notman Studio. John Fraser, artist).



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☞ The FIRST PRIZE was awarded to our firm at the Provincial Exhibition held in Brantford in 1857, also in 1859 at Kingston, for the best Ambrotypes; also the best Photographs from Miniature to Life Size, coloured, in oil.

Fig. 7.22: Photograph heavily overpainted with oil colors. Photographer's label on the verso (Portrait of the Prince of Wales. Carson's Studio, Toronto).

The treatment of handcolored photographs is an area requiring considerable research. A large area of concern is the effect of the coloring pigments, dyes, and binding media on the photographic image-forming substance. This was the subject of a research project in the Photograph Conservation Lab at the National Archives of Canada. The study involved the accelerated aging of a variety of coloring media applied to three different types of laboratory produced photographic test strips. Salted paper prints, albumen prints, and Kodak Azo F2 (silver gelatin) prints were all tested with a variety of binding media including Acryloid B-72, Elvace No.1874, gelatin, gum arabic (acacia), linseed oil, sodium carboxymethylcellulose, and turpentine. Coloring media included 17 different Winsor and Newton's Artists' Water Colours, 7 Ilford Cibachrome Retouching Colors, 9 Kodak Dry Dye Retouching Colors, 6 Marshall's Photo Pencils, and 7 Marshall's Photo Oils, plus Marshall's Duolack, Extender, and P.M. Solution. The results of the tests were wide ranging yet specific enough to make tentative recommendations for the use of some pigments over others. Winsor and Newton's Artists' Water Colour pigments, with a few exceptions (French ultramarine, vermilion, cadmium red and yellow, and ivory black) were considered relatively nonreactive as were the Marshall's Photo Pencils and the Cibachrome and Kodak Retouching dyes. The other materials were somewhat more reactive.

When considering the results of this investigation, one must keep in mind that Cibachrome Retouching Colors and Kodak Dry Dye Retouching Colors are designed and intended for use with specific color materials, Cibachrome prints and Kodak chromogenic materials respectively. They were not designed for use with black-and-white materials. Also, while Marshall's oils are designed for use with black-and-white materials, they are not intended for use in restoration work. However, this study is extremely valuable for the identification of certain reactive pigments.

7.11 Repair of Cracked and Lifting Emulsions

Little investigation has been carried out in the area of the repair of damaged emulsions, although this is a common problem in collections of historical photographs and negatives. The causes of the cracking and lifting of emulsions are varied and require different solutions, depending on the kind of photograph involved. Generally, because the emulsion layer is so fragile and the repair work so labor intensive, these treatments should be carried out by more experienced conservators. They are not practical for treatments of large collections of damaged glass negatives, for example, but can be successful with single, relatively important items.

Before discussing treatment methods for each kind of photograph that may exhibit this kind of damage, it is well to examine the alternatives to treatment, in those cases where treatment cannot be carried out immediately or at all, due to the large number of items damaged or a lack of staff and funding. An interim solution is to encase the original image in a protective housing, such as a Mylar folder or a mat. Mylar (polyester) tends to hold static electrical charges that can attract pieces of flaking emulsion, tearing them from their support and therefore should not be used for flaking materials. Alternatively, the image could be sandwiched between two sheets of glass, to prevent abrasion that would result in the loss of emulsion particles. A heavy paper spacer, approximately $^1/_4$" wide, should be placed around the edges, between the emulsion and the protective glass as a piece of glass resting directly on the damaged emulsion could augment the problem. While the items await treatment, it is important that they not be handled or moved excessively. It may be advisable to flatten the flaking emulsion under a sheet of glass, then copy or duplicate the photograph or negative, to ensure that the information in the image is not lost.

Tintypes

Tintypes are thin sheets of iron, one or both sides of which have been painted with a black lacquer. A wet collodion emulsion was applied to the black surface by the photographer shortly before exposure. Subsequent to processing, the collodion surface was often protected with a clear varnish layer. Damage to tintypes generally takes the form of mechanical damage, from poor storage and handling, in the form of chipped or cracked emulsion layers. The collodion emulsion is quite brittle, and the iron support easily bends. It is this combination that causes the tintype to be vulnerable. Furthermore, the support plate itself can rust. The corrosion products damage the emulsion by blistering it and forcing it off the plate.

There have been few thorough tests completed involving repairs to collodion emulsions. Therefore, rather than use methods or materials that may inflict further damage, it may be wise to copy the original and make the surrogate image available for researchers. However, corrosion products can be gently lifted off where the emulsion has already been lost using a fine pin tool. These areas can then be carefully consolidated and inpainted with a high quality artists' acrylic paint.

The tintype should be matted and protected in a sandwich scheme, as described elsewhere in this chapter. The use of a glass-plate sandwich is not appropriate for bent tintype plates, as they must not be flexed, even to flatten them, for fear of cracking the emulsion. However, based on Alice Swan's method for housing daguerreotypes (Swan, 1981), special enclosures can be constructed that accommodate the warpage of the plate (see Figure 7.46).

Albumen Photographs

Albumen prints consist of a printing-out emulsion on an extremely thin paper support. The emulsion is made from egg albumen and sodium chloride, sensitized with silver nitrate. Albumen emulsions characteristically have a network of fine cracks across the entire surface of the print. Due to the thinness of the paper, mechanical damage, as a result of careless handling and storage, takes the form of creases and tears in unmounted albumen prints. An albumen photograph that was mounted on a poor quality, highly acidic board can be damaged when the mount becomes brittle and breaks, carrying a portion of the photograph with it. If the paper support has deteriorated, the emulsion may lift off the support. Albumen photographs that are stored in areas with less than the recommended minimum relative humidity level may have desiccated emulsion layers that result in severe cracking and peeling of the emulsion. You can use a very fine retouching brush and a dry mixture of methyl cellulose to re-adhere flaking and peeling albumen emulsions. A small amount of adhesive is gently applied on the underside of the lifting emulsion. The portion of the emulsion layer is then laid flat with a fine brush and very gently burnished through polyester webbing using an agate burnisher. The repaired piece is weighted with a piece of polyester webbing, some blotting paper, a square of Plexiglas, and a weight. The emulsion becomes softer and more vulnerable when any moisture is introduced. Thus, great care must be taken with this procedure, lest more damage be done to the picture. Enough moisture, by way of the adhesive, must be applied to relax the emulsion so that it lies flat. Too much moisture results in cockling of the paper support, making it difficult to flatten the lifting emulsion and the print itself.

Wet Collodion Glass Plate Negatives

These early negatives on glass carry an emulsion made of cellulose nitrate (gun cotton) dissolved in alcohol and ether and flowed onto a glass support by the photographer. The plate was sensitized, exposed, and processed before the collodion dried. A clear layer of varnish was usually applied after processing to protect the negative from scratches and dirt. The most common damage to collodion negatives is the most obvious: breakage of the glass support. It is also common to find collodion emulsions that are flaking off the glass plate, particularly in collections that have been improperly stored or have suffered damage from water. Very little research has been carried out regarding the re-attachment of flaking collodion emulsions. Because the support layer is clear and because one may need to make prints from the repaired negative, any adhesive used for repairs must match the refractive index of the glass.

Other solutions may be applied. Flaking wet collodion negatives can be protected with a single sheet of (or between two sheets of) clean, ordinary window glass, secured with either cloth tape, "archival" mending tape or Japanese tissue adhered with a PVA emulsion. Whatever is used, the bond must be strong enough to stop the glass from shifting. Again, a heavy paper spacer is required keeping the cover glass from sitting directly on the emulsion. Before mounting, you may wish to duplicate the negative, so that a surrogate exists for research use.

Silver Gelatin (Dry Plate) Glass Negatives

Dry plate negatives are composed of sheet glass coated by commercial manufacturers with a silver gelatin emulsion. As with collodion negatives, the most common kind of damage is breakage of the plate itself. Additionally, if the emulsion becomes desiccated, it can shrink and pull away from the glass. These flakes are extremely brittle and will easily snap. A fine brush can be used to apply a 5% solution of gelatin dissolved in distilled water at 50°C. The solution will soften and relax the emulsion gelatin and can act as an adhesive to re-attach the flakes and particles to the glass support. Unfortunately, as the flaking emulsion relaxes, it expands and lining up loose wet flakes with firmly adhered emulsion can be difficult — they don't always stick once dry. This procedure requires great patience and manual skill and should be carried out by more experienced conservators. Because it is a labor-intensive treatment, it is not appropriate for large numbers of damaged dry plate negatives.

Alternative solutions include the duplication of damaged dry plate negatives, with the flaking emulsion temporarily pressed flat by a sheet of plate glass. A damaged negative can be protected in a sandwich of ordinary window glass with a spacer, as previously described.

Fig. 7.23: Flaking gelatin emulsion, before and after consolidation with a warm gelatin solution.

Silver Gelatin Prints

If poorly handled and stored under less than ideal conditions, silver gelatin photographs can become desiccated. Like dry plate negatives, their emulsions can crack and lift from the support layer. The print can be humidified to re-introduce moisture into the gelatin. Humidification is discussed in Section 7.8 (Flattening Prints and Negatives). Many cracks will close up temporarily after this treatment. Major cracks that have lifted substantially can be laid down with starch paste, methyl cellulose, or gelatin applied under the lifting emulsion on a fine brush and then weighted until dry. The moisture should relax the flake enough for it to lie flat and re-adhere to surrounding gelatin surfaces. As a further strengthening and repair measure, after the flaking and lifted areas have been re-attached and while the print is still relaxed from the humidification, the entire surface of the photograph can be brushed with a 2% warm gelatin solution (50°C), using a wide, flat brush. This will help to keep the small fissures closed. Brushing should be done quickly and lightly, using horizontal and vertical sweeps across the entire surface. (You can experiment on discarded photographs to observe the effects of various gelatin solution strengths.) This treatment should be restricted to severely damaged emulsions as it will affect the surface gloss of the print and may be considered unethical on less damaged materials. Once air dried, the print can be lightly humidified and then pressed between weighted blotters. Polyester webbing should be placed against the emulsion side to stop the gelatin from sticking to the blotters.

7.12 Repair of Broken Glass Plate Negatives

Glass provides the support for ambrotypes, wet collodion glass plate negatives, silver gelatin dry plate negatives, Autochrome plates, and lantern slides, to name the most common kinds of breakable images. Because these negatives and positives are commonly brought out for researchers to study, and used to produce modern prints in some collections, a recommendation to retire the objects to long-term storage may not be appropriate. Yet any amount of handling entails serious risks of chipping and breaking the glass support and damaging the relatively fragile emulsion layer.

A very practical solution, to prevent such occurrences, would be to provide high-quality copies and duplicates for research and printing use, with the original items brought out to researchers only in exceptional circumstances. Alternatively, collections of negatives can be microfilmed by transmitted light (on a light table) to provide researchers access to collections that cannot be handled. This is a particularly good solution for large collections, where it is not feasible to duplicate every negative.

An inexpensive and easy method to stabilize glass negatives has been in use for years at many institutions. The original negative simply is secured with an appropriate tape (either Japanese tissue and PVA emulsion, Archival mending tape, or linen tape using the minimal amount of moisture) to a clean sheet of window glass ("astronomical" glass can be substituted where optical purity is required) with the emulsion facing inward. If the negative is broken into more than two pieces, it may be necessary to construct a sandwich of two sheets of glass. Any duplication work should be carried out before the glass is secured by tape, to prevent the package having to be re-opened later. If a large-format enlarger is available, the packaged negatives can be projected for duplication. There are, however, certain problems with this solution. The added bulk and weight from the additional glass may exceed the limits of the available storage space. If the broken negative is in frequent demand for printing (and no large format enlarger is available), the package must be re-opened and resealed each time, unless a duplicate negative can be substituted.

A research project carried out in the Photograph Conservation Laboratory investigated the use of epoxy adhesives for the repair of broken glass plate negatives (Antonacci, 1979). In addition to the requirement that the materials cause no damage to the photographic emulsion, two problems existed: it was necessary to match the refractive indices of the glass and adhesive and to find an adhesive that would bond to a non-porous material like glass. After thorough testing of various adhesives and procedures, "Epoxy Glass" was selected for its relative stability in aging studies, for the closeness of its refractive index to that of glass, and for the strength of its bond. HXTAL NYL-1 EPOXY has, more recently, been suggested by the Canadian Conservation Institute as being suitable for glass repair and is used widely by them on archaeological glass.

To keep the pieces together during bonding, gravity was used: the pieces were supported on a Plexiglas stand on which the plate was supported at an angle, emulsion side up. In this procedure, a small quantity of adhesive is applied in dots at regular intervals along the break edge. A piece of Mylar is placed underneath the negative so that the plate will not stick to the Plexiglas stand. The excess adhesive on the non-emulsion side is removed the following day, after the epoxy has set, using a sharp scalpel. Any adhesive on the emulsion side must be removed immediately using the appropriate solvent.

Often, pieces of a broken plate are missing, making reassembly difficult or impossible. In this case, the plate can be assembled on a sheet of paper and the exact shapes of the missing pieces recorded. Similarly, a piece of tracing paper can be laid on top of the assembled plate and the shapes of the missing pieces traced. Four-ply acid-free mat board can be cut to the exact shapes of the missing pieces and inserted to complete the assembled plate.

Fig. 7.24: Materials and apparatus for the repair of broken glass plates.

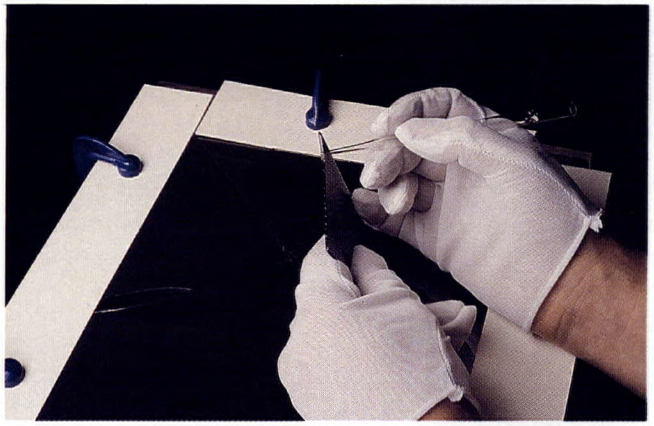


Fig. 7.25: Adhesive being applied to plate edges, grooved Mylar seen below the plate.

Fig. 7.26: Adhered pieces of glass plate drying on the stand.

This treatment presents certain conservation problems, however. It is an extremely labor-intensive treatment and thus can be applied to only a few relatively valuable images. Also, we know little about the long-term aging properties of epoxy adhesives. We don't know if the bond strength will be maintained or if the material will maintain the same refractive index over decades or centuries. Furthermore, the epoxy treatment is not generally reversible. Finally, it may still be necessary to provide some support for the negative in storage, particularly where several breaks exist in one negative (Figure 7.27).

The advantages of this treatment are two-fold: the emulsion layer is protected from further damage along the break; and the storage space requirement is reduced, as it is no longer necessary to wrap broken fragments separately for storage, nor is it necessary to use two sheets of window glass to stabilize a badly broken negative.

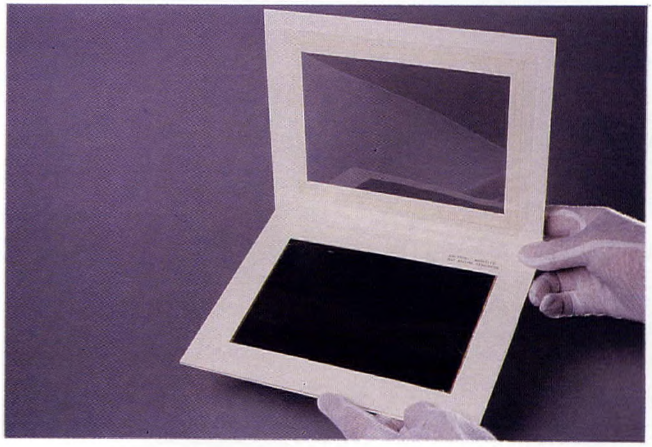


Fig. 7.27: Storage folder for repaired, yet fragile negatives.

For valuable but broken negatives that need special support and yet must be accessible and visible by transmitted light, see Figure 7.28. First, a small frame, the same thickness as the plate, is cut from rag board with inside dimensions the same as the dimensions of the plate. The cover glass is cut 1 cm larger than the dimensions of the negative. A second small frame is then cut for the cover glass, the inside dimensions of which are the same as the dimensions of the cover glass. Two identical bevelled window mats are then cut with inside dimensions approximately 0.5 cm smaller than the

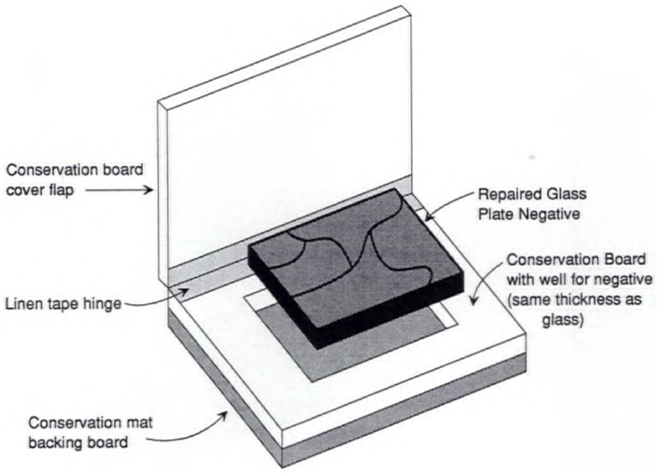


Fig. 7.28: Glass and mat support for broken glass plate negatives.

dimensions of the negative. One sits on either side of the package. The outside dimensions of the frames and window mats are the same. The package is then assembled, and the two frames are joined using double-sided tape (3M No. 415). The negative and cover glass are then inserted with the emulsion facing out. One window mat is attached to the cover glass side using double-sided tape. The opening of the second window mat is covered with Mylar (3 mil) and attached with double-sided tape. This mat is then hinged at the top. The Mylar on the mat will sit against the emulsion side of the negative. This construction provides maximum protection for the glass plate as well as visibility and allows the negative to be removed, if required, for printing.

7.13 Retouching

Conservators often debate the ethical issues involved in retouching photographs after repair and in-filling treatments. The controversy revolves around the question of the photographer's original intentions and the integrity of the original image. The introduction of a conservator's brush strokes modifies the original in such a way that its integrity could be compromised. The Photograph Conservation Laboratory takes a middle ground approach: conservators retouch to the point where in-fills, repairs, and abrasions blend into their surrounds. We do not retouch any surface of the original emulsion or image, unless abraided. This kind of retouching is almost but not entirely invisible to the casual observer. When total loss of detail has occurred (such as a sitter's or subject's head missing where emulsion has flaked off, or a store-front sign obliterated by a tear), the conservator must never presume to carry out the intentions of the photographer by inventing that part of the image. It is acceptable, in our view, to simply reduce the visual impact of losses and damaged areas. Photograph conservators are not restorers. We don't return the artifact to its original condition. Indeed, when dealing with historical photographs, we don't even know exactly what the image tone and surface gloss looked like originally. (This same dilemma exists for the conservator who subjects photographs to chemical restoration. The ethical implications of chemical treatments are discussed in Chapter 8.)

From its earliest days, photography and retouching have gone hand-in-hand. Photographers themselves and artists hired by studios especially for this task applied paints, inks, charcoal, and various colored powders to photographs and negatives. Opaque carbon-based inks and graphite pencil strokes were commonly used. (Retouching fluid applied to glass negatives often appears today as a blue cast or as flat black areas and is most apparent — in the form of increased density — when one attempts to print such 19th-century negatives.) On various color print materials, the retouching dyes often fade at different rates than the photographic dyes. Other retouching dyes are made up of the same dyes used in the emulsion and therefore fade at a similar rate. Unfortunately very little research has gone on in this area. Newspaper photograph archives contain many photographs on which entire sections of the image have been painted out, and which show heavy overpainting around the edges of subjects, to make them stand out from the background when photomechanically reproduced on newsprint. In the absence of information about the effect of retouching on the long-term stability of the image, and in the presence of concern about the integrity of the original photograph, a conservator should not attempt to remove or modify retouching that may be found on an original image. We discuss below only those methods and materials that can be used to make repairs less visible.

Prevailing conservation ethics require that all treatments be reversible. This includes retouching, which should be removable from the photograph without affecting the original in any way. For this reason, one may need to place an isolating layer of gelatin or methyl cellulose between the photographic paper and the retouching medium, to ensure that the retouching can be removed. This precaution is essential when retouching colors would bleed uncontrollably onto the paper fibre.

Several retouching media and procedures are available for photographic materials. The image tone, surface gloss and texture, image and emulsion type, graininess of the image, and size of the area to be retouched all determine the choice of medium and procedure. Most retouching materials are water-based, for ease of application and removal. However, this becomes a problem when retouching photographs that are highly soluble or reactive to water, such as starch prints. In these cases, dry pigments in the form of retouching pencils can be used effectively, or dry pigments used in non-aqueous solutions.

The conservator must attempt to match the surface gloss of the photographic emulsion. Pigments can be added to a 2%-5% solution of gelatin to provide a glossy surface for gelatin prints. Methyl cellulose can be used for providing mat or semi-mat finishes. Certain retouching colors, such as those provided in the Cibachrome retouching kit, dry to a high-gloss finish, to match the gloss of Cibachrome prints. Dry pigments can be suspended in various resins, such as Acryloid B-72 dissolved in toluene, to simulate a photographic emulsion. Synthetic resins are extremely difficult to remove from paper fibres and therefore should not be used directly on original material, but rather restricted to infills.

Fig. 7.29: Repaired photograph prior to and following retouching.

Retouching colors are applied to photographs using a very fine brush. The color is applied with a barely moist brush, in a series of tiny dots, rather than in broad brush strokes, which are always streaky and highly visible. The eye sees the dots as blended. For large fills, an airbrush may be used. Regardless of the procedure chosen, retouching should not interfere with the original image areas in any way. Furthermore, areas (such as dust spots) that were not originally retouched by the photographer are never retouched.

The following is a list of materials commonly used to retouch photographs.

Black-and-White Retouching Materials

- Kodak Spotting Colors (black, white, and sepia)
- Winsor and Newton's Artists' Water Colour Series I (dry cakes)
- Spotone retouching fluids (Retouch Methods Co., Inc.) (in olive-, blue-, and neutral-black shades)
- Gamma Photo-Retouch Kit, M. Grumbacher Inc.
- Marshall's Photo Pencils

Color Retouching Materials

- Winsor and Newton's Artists' Water Colour Series I (dry cakes)
- Kodak E-6 Transparency Retouching Dyes
- Kodak Ektachrome Film Retouching Dyes
- Kodak Retouching Colors (9 colors plus remover)
- Kodak Liquid Retouching Colors (9 colors)
- Color Print Retouching Colors (Retouch Methods Co., Inc.)
- Ilford Cibachrome Transparent Retouching Dyes
- Marshall's Photo Pencils

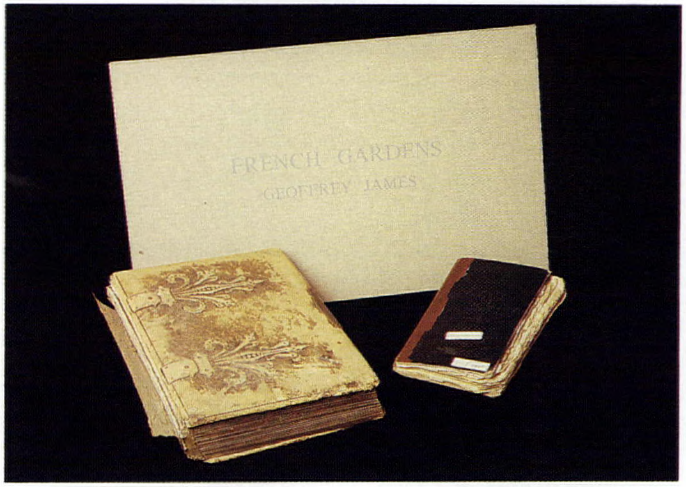


Fig. 7.30: Album, scrapbook, and portfolio.

7.14 Conservation of Albums, Scrapbooks, and Portfolios

Introduction

Photographic albums, scrapbooks, and fine art portfolios provide a convenient means of organizing a collection of images. Storing related material in one volume ensures, to some degree, that the integrity of the collection is maintained. Depending on the type of material used in the album and the physical abuse it has been subjected to over the years, it can be an ideal storage method.

Fine art portfolios, generally constructed of better quality materials, are often maintained in good condition as they tend to start out with a much higher intrinsic value. Early albums designed to hold photographs are often made of better quality materials and are handled with greater care than notebooks or scrapbooks, which are usually constructed of very poor quality materials — often the weight of the paper and the adhesive used are inappropriate for mounting photographic prints.

The degree to which an album, scrapbook, or portfolio receives treatment is dependent on the relative significance or value of the object established by the curatorial staff, the quality and condition of the materials used, the amount of use the object receives, and the availability of expertise and resources to adequately perform the conservation treatment.

Due to the complex nature of albums, the treatment they receive must be determined on an individual basis. Standardizing treatments, as is possible with certain archival records, should not be considered. Once it has been decided to treat an object, devising an appropriate treatment requires expertise from three main sources, the curator, the conservator, and the conservation bookbinder. The first major decision is to determine if the object should be completely disassembled; second, should the object be rebound; and third, if so, should it be returned to the conserved original binding or to a new binding. Once these decisions have been made, all options can be explored and complete treatment proposals developed.

This section of the study guide will discuss three treatment options for albums. Of course, multiple options exist, as well as variations on the options presented here; however, all are dependent on the unique requirements of the object itself. The options to be discussed in this section include:

A. Repair the album (binding, pages, and photographs) without disassembly; rehouse in a protective storage box.
B. Disassemble the binding; dismount the photographs and repair and sleeve them; store binding and loose photographs separately.
C. Disassemble binding; dismount and repair photographs; remount onto conserved original pages or new album pages; rebind into conserved original binding or into a new binding.

Treatment Option A

Option A involves minor repair to the binding, album pages and the photographs themselves, followed by housing the album in a protective storage box. This option can be applied to albums that are in reasonably good condition or can be used as an interim measure when time and/or resources do not permit a full treatment. Standard paper conservation repair techniques outlined in this chapter can be applied to the album pages and the photographs on a page-by-page basis. Binding repairs to be carried out under the supervision of or by a conservation binder can include consolidation of flaking or lifting binding materials, repair to spines, corners, labels, etc., and reattachment of jackets to text blocks. Interleaving tissue may also be required where the surface of the photographs has been abraided by objects mounted on opposite pages. Interleaving tissue should be very thin, pure fibre paper, adding as little bulk as possible to the text block. Large quantities of tissue could distort the text block, adding stress to the binding, causing it eventually to break apart. If a binding is particularly fragile, it should be stored horizontally and its access restricted; when handled, lintless white cotton gloves should be worn.

Protective storage boxes, generally constructed by the conservation binder, should be custom designed and constructed for the particular album in question using stable materials. The album should not be free to move around inside the box as damage could result from even minor shocks. Boxes that are too small can cause warping of the binding boards and text block and abrasion of the binding materials every time the album is removed from or returned to the box. If the album is to be shelved vertically, and the text block is recessed in from the binding boards, a support should be incorporated into the base of the box to inhibit sagging of the text block.

Designs for storage boxes tend to be standardized, are generally of the "clamshell" configuration, and can be adapted to accommodate a variety of shapes and requirements, including separate compartments for storing miscellaneous materials such as original bindings when new bindings have been completed. Consult *Boxes for the Protection of Rare Books: Their Design and Construction*, a volume compiled and illustrated by Margaret R. Brown; it contains thorough diagrams, materials lists and instructions for the manufacture of storage boxes suitable for photograph albums (Brown, 1982).

Treatment Option B

Bindings that are of no intrinsic value or are contributing to the deterioration of the photographs may be considered disposable by the curatorial staff. Also, the photographs themselves may be of little significance as a "collection" and, for these reasons, an album may be taken apart, the photographs treated and housed separately, and the binding either disposed of or stored in another location. Obviously, the value of the binding itself must first be determined and if deemed of little or no value, the pages can be cut out, facilitating the dismounting procedure. If the binding is to be maintained intact, dismounting will be carried out on a page-by-page basis.

The removal of prints from album pages should be done following the procedures outlined in Section 7.3 of this chapter. The type of photographic emulsion and the condition of the object will determine the procedure used. Removing images from bound pages can be difficult and time consuming as free-flowing liquids are generally not allowable. The use of poultices applied to the verso of the page or carefully controlled local applications of moisture are the most likely means of dismounting. Brittle, weak adhesives may permit dry removal.

Following dismounting, residual adhesive should be removed from the verso of all prints, the print repaired if necessary, followed by flattening. The images can then be individually sleeved in polyester sleeves or placed in high quality storage envelopes (see Chapter 9 for more details on filing enclosures and storage procedures).

The disassembly of an album requires extensive pre-treatment photographic documentation. It may be important in the future to know how a collection was assembled and presented. If possible, every page should be documented with color transparencies and black-and-white negatives.

Fig. 7.31: Pages from the album prior to treatment.

Treatment Option C

Option C requires considerable resources and is generally restricted to albums of great intrinsic and historic value. The removal of all prints from the album and rebinding in either a new, historically correct binding or in the completely restored original binding requires considerable expertise in all areas.

In order to better illustrate this option, a treatment performed on an album in the collection of the National Archives of Canada will be detailed here. The Jacobs album, deemed to be the most historically valuable album in the collection, contained more than 900 individual albumen prints all dating from the 1860s. The album originally consisted of three separate volumes, but by the time it reached the conservation department, all pages had been cut from the bindings and only two of the jackets remained. The page paper varied slightly but was generally a poor quality, off-white wove paper, and medium to light weight. Except for the images previously mounted on board (*cartes-de-visite*, etc.), all photographs were buckled and cockled due to the weakness of the paper and the strength of the adhesive. The pages also contained hand-written ink inscriptions, most water soluble, and decorative floral motifs in graphite, black ink, and one in watercolor, also soluble in water.

The bindings were beyond salvage; however, the collection format and presentation were deemed important and maintaining the inscriptions was essential. Therefore, it was decided, in consultation with curatorial staff, conservation binders, and the conservator, to remove the photographs from the original pages and mount them into new albums that preserved, to some degree, the historic integrity of the original volumes. The original pages were to be treated and stored separately.

Binding options were presented, including account style and post binding. The latter was chosen as it allowed individual pages to be removed for research and display. The new binding design (half leather and cloth) matched the original jackets, and the size was increased so that a margin could be included on the album pages. This was done in order that the photographs would not be sitting directly against the edge of the page thereby being subjected to mechanical damage when the pages were turned. The paper selected for the new pages was 100% rag, cream colored, hot pressed for a smooth finish, and medium to heavy weight.

The photographs were repaired and all lined with Japanese tissue and wheat starch paste. To avoid deformation of the album page from wet mounting, a non-aqueous, solvent activated adhesive was used to mount them onto the new pages. The adhesive used was Rhoplex AC-234 applied to very fine Japanese tissue. The tissue was applied to the verso of the prints, trimmed, and then solvent activated and applied to the album page. Mylar templates were made of the original pages prior to dismounting to ensure that the exact

Fig. 7.32: Original album page viewed by raking light.

Fig. 7.33: New volume showing post binding and interleaving tissue.

page configuration was maintained. Also, interleaving tissue was incorporated onto every page to protect the images from abrasion. Images originally mounted on both sides of one page were placed on two separate pages in the new album.

The original album pages, following dismounting of the prints, were treated, flattened and photocopied onto a high quality paper that matched the color of the new album pages. The photocopied inscriptions were then trimmed and added to the new pages.

Separate protective storage boxes, as described in Option A, were constructed for each volume as well as for the original bindings and album pages.

Fig. 7.34: New album page showing photocopied inscriptions.

7.15 Matting

Matting provides excellent physical protection for photographs on display and in storage. It is one of the least controversial and safest preservation solutions. On the other hand, the materials are expensive, the procedure takes time, and the materials require many times the amount of storage space required for a photograph stored in a Mylar sleeve or paper envelope. Matting is not an appropriate solution for large collections, or for institutions with limited budgets and storage space, except for relatively valuable individual images.

Matting Materials

The matting of photographic materials for long-term storage, or even extended display, requires the use of high quality materials. Although more research is called for in this important area, at this time the recommended matting material for all photographs is a neutral pH 100% rag board, or an acid-, sulfur-, and lignin-free purified wood pulp, non-buffered board. Most contemporary museum-quality mat boards have an alkaline buffer incorporated either in the surface paper, or throughout the board, which raises their pH to approximately 8.5-9.0. The use of alkaline buffered materials to store photographs was called into question a few years ago. As most photographic materials are slightly acidic, it was thought that an alkaline environment might promote deterioration. This was not thoroughly investigated and the general feeling now is that some buffered materials may be acceptable for most photographs. However, some materials, certainly cyanotypes, are adversely affected by an alkaline environment and should be housed accordingly. Hinging materials and photo corners also should be made from pure-fibre papers or from polyester (Mylar), which is inert.

Mat and Back Board

The first part of a mat consists of a back board, a solid board onto which the photograph is hinged or attached by corners. This back board is taped securely to a window mat, which lies flat on top of the photograph, with a window cut out for the image. The edges of the photograph are held flat by a slight overlap of the window mat. Both window mat and back board should be made of the high-quality, neutral-pH materials described above. Unless the matted image is to be immediately framed, it is advisable to place a piece of thin Mylar or translucent acid-free tissue under the window mat, on top of the photograph, to protect it from dirt and abrasion.

Photographs that are solidly mounted onto a thick, heavy mount board may require a spacer between the back board and the window mat. The spacer should be the same thickness as the mounted photograph and sit around it to raise the window mat to the level of the image. These are referred to as Sink mats.

The curator should always be consulted; historical considerations may influence the design of the mat and mount. For example, a cabinet card may need to be attached in such a way that it can be easily lifted to view the imprint on the verso. A curator may prefer the use of Mylar corners rather than have hinges attached to a photograph that carries a verso inscription. A double window mat

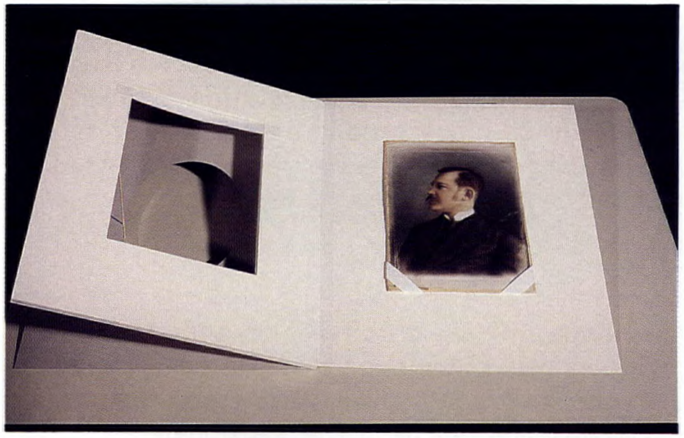


Fig. 7.35: This handcolored photograph, adhered to an embossed metal plate, is mounted into the mat using photo corners. A heavy spacer has been incorporated between the window mat and backing board to raise the mat off the embossed surface.

may be needed to allow museum visitors to view simultaneously both sides of an image on display, where the verso contains valuable information. Certain images may need to be seen in their entirety, precluding the use of an overlapping window mat. A matted carbon tissue image may be best viewed through the transmitted light allowed by a double window mat construction.

Aesthetic considerations play a role in the design of the mat. It is more pleasing to leave a larger bottom margin to the window mat than to have top and bottom margins of equal width. For smaller prints, the bottom should be approximately 1/2" larger than the top edge. For very large prints, the bottom should be approximately 1" larger.

Hinges

Before pasting, the print is centered inside the window mat. Using two or three strips of heavy Japanese tissue and wheat starch paste, the photograph is attached to the back board. Half of the strip is attached to the back of the photo; the other half is attached to the back board. To attach the hinges to the photograph, the paste is applied to the hinge only and then attached to the photograph. It must be sandwiched between polyester webbing and blotters and weighted until thoroughly dry. The print is then correctly positioned and the other end of the hinge adhered to the backing board. Two additional strips of tissue are pasted onto the back board, atop and perpendicular to the first strips, to hold them more securely. They are sandwiched and weighted until dry. This system has several variations. It is not designed for heavy, mounted photographs, the weight of which would tear the hinges (Figure 7.36).

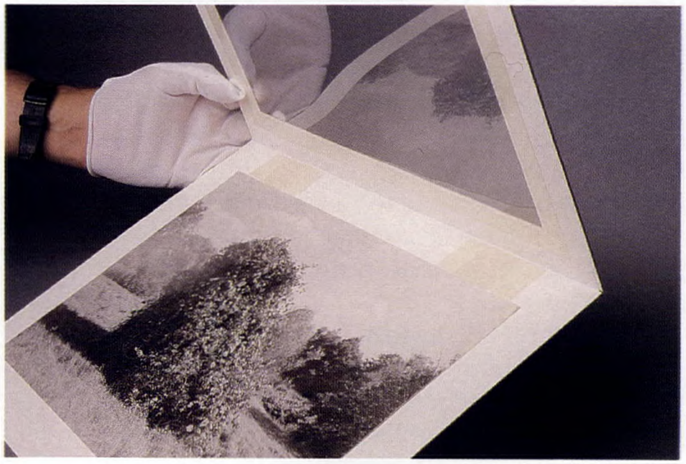


Fig. 7.36: T-hinges used to secure the print in a window mat.

Resin-coated papers cannot be hinged with an aqueous adhesive, as they tend to leave bulges and puckers on the image side of the print, which are somewhat disfiguring. Unmounted albumen photographs respond in a similar way to aqueous adhesives. Using wider hinges and more of them that extend into the print by only 0.5 cm minimizes the effect of the adhesive on the emulsion side. The use of a non-aqueous adhesive for this purpose has received little attention to date. Heat-set or solvent-activated adhesives applied to Japanese tissue could be used; however, the stability of the print emulsion should be thoroughly tested first. Solvent-activated adhesives could result in the migration of adhesive into the photographic paper potentially causing staining in certain types of prints. Obviously, prior testing is required.

When photographs are being mounted into window mats that do not cover the edges of the photograph itself (float matting), blind or V-hinges can be used, provided the print is very flat and there is no danger of it curling. The hinge is pasted to the photograph and, when dry, it can be folded under the print and pasted to the backing board and a second piece of tissue added to the backing board over the hinge, securing it (Figure 7.37).

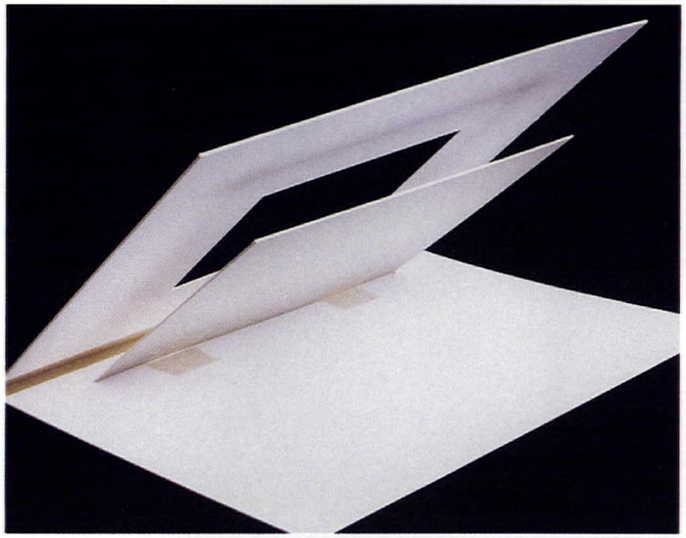


Fig. 7.37: V-hinges used to "float" the print in a mat.

Photo Corners

It may be necessary or desirable to avoid the use of adhesives and hinges altogether. Photo corners can be used. These corners attach to the back board and secure all four corners of the photograph to this support. Corners can be made from Mylar strips held onto the back board by archival-quality double-sided tape (such as 3M No. 415). They also can be constructed from a heavy non-buffered, pure-fibre paper, taped down with linen tape. The latter method works well for large pieces and heavy mounted photographs. Large unmounted works require larger, tighter fitting corners, to counteract the tendency of the print to sag. The window mat must overlap the print edge and conceal the mounting corners. The corners should be slightly loose to accommodate dimensional changes due to fluctuating environmental conditions.

False Margin Mat

Some photographs should be seen from edge to edge. In such cases, the window mat cannot overlap the photograph edges. Although a floating mat (which has an opening larger than the photograph by a small margin) would solve the problem, such a solution will not work with images that curl at the edges, for example. In other cases, photo corners obscure too much of the image. The false

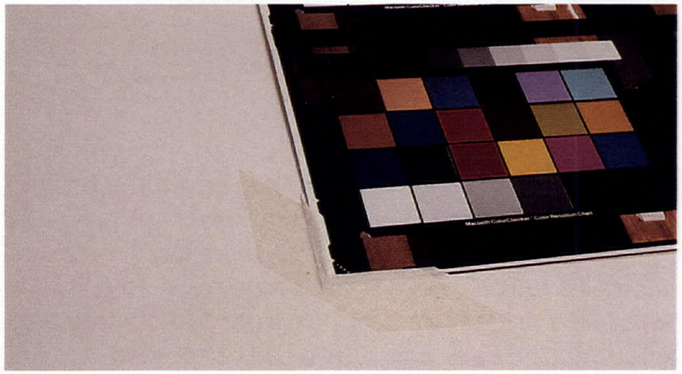


Fig. 7.38: Photograph secured in a mat with photo corners.

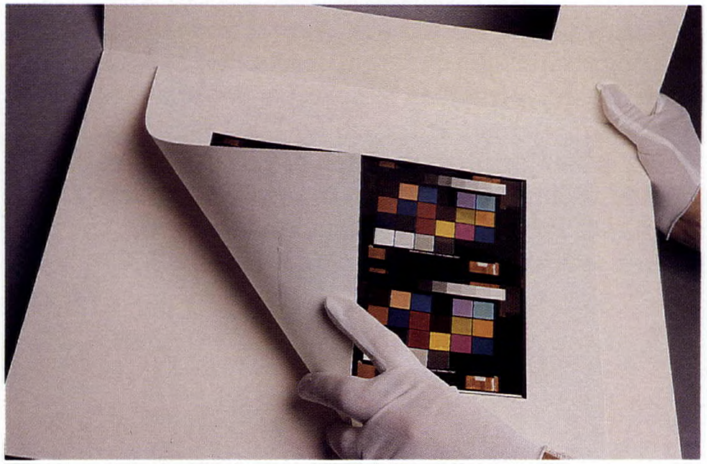


Fig. 7.39: Photograph float mounted using a false margin.

margin adds a margin to all sides of the print onto which the window mat can overlap. The print is laid on top of a piece of heavy paper that is larger by two or three inches on all sides and is of an appropriate color and texture. The dimensions of the photograph are marked off on the paper. The print is removed and a square or rectangle cut out that is approximately 1/8" to 1/4" smaller than the dimensions of the photograph. The edge around the hole is then chamfered to fit the photograph exactly. The edge of the opening is lightly pasted and stuck to the verso edge of the photograph, to form a border around it. The assembly is pressed until completely dry. The photograph can be hinged into a mat, placing the hinges on the verso of the false margin. As false margins can add considerable stress to objects, they should be used only on very sturdy materials such as resin-coated papers or prints on pigmented polyester supports such as Cibachromes.

Access Sandwich

This matting method is used primarily for heavily used research collections or items where the researcher needs to view both sides of the image. Photographer or studio imprints and inscriptions are often found on the verso of photographs and may be considered an integral part of the object. Cut two window mats that are the mirror opposite of each other. The openings should be 1/4" to 1/2" larger than the piece to be displayed inside. Mylar should be applied to the inside of the window openings of both mats, using double-sided tape. The two halves are then dry-mounted together, leaving an opening on one side of the mat to allow the photograph to be inserted. The photograph will be held in place by the tension from the Mylar on both sides.

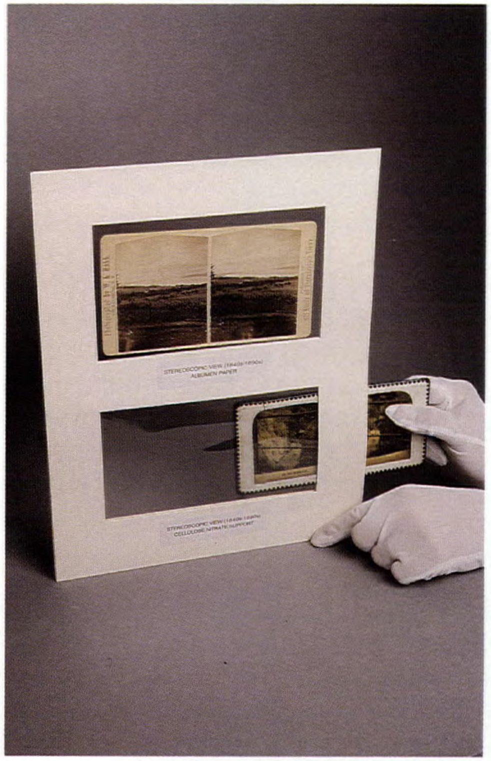


Fig. 7.40: "Access sandwich" mount.

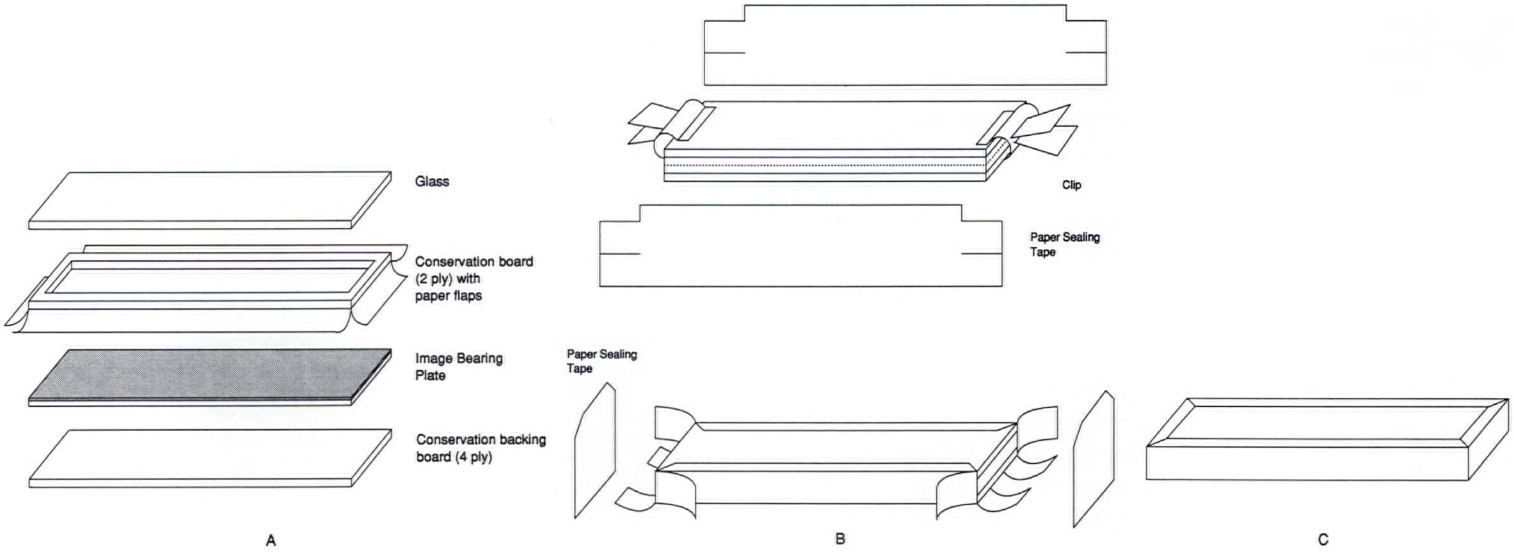


Fig. 7.41: Sealed protective housing for daguerreotypes.

A. The small mat with paper flaps is laid onto the image. The flaps are wrapped around the image-bearing plate and adhered with a high quality PVA adhesive. If an ambrotype is being housed, wrap the flaps around the conservation backing board as well and adhere.
B. The package, including the cover glass and backing board, is clipped together and then sealed around the edges with paper tape and PVA adhesive.
C. The sealed package is ready for storage or display.

Storage-Display Cases for Tintypes or Daguerreotypes

Certain kinds of encased images may be found in collections without their cases. A special kind of mat sandwich incorporates glass into the design, to provide the same kind of protection that would be afforded by a 19th-century case as described in Chapter 5. The design reproduced here was developed by Alice Swan and can be used for the protective housing of daguerreotypes, ambrotypes, and tintypes (Swan, 1981). Also, this assembly can be placed directly into a frame for exhibition. The major advantage of this mount, however, is the protection it provides the image, not only from mechanical damage, but from air-borne pollutants as well.

7.16 Framing

The framing of photographs is often carried out by photograph conservators. In those institutions with separate exhibition offices that prepare items for display, conservators would be consulted about the proper materials and methods of framing. Therefore, although the framing of photographs is rarely an appropriate or feasible preservation strategy (due to cost and space considerations), it falls within the domain of the photograph conservator. Provided the proper materials are used, a photograph in a frame is well protected, whether on display or in storage. Methods vary according to the display environment and the kind of photograph involved.

Certain guidelines should be followed for all photographs in frames. (Certain issues mentioned below will be discussed in greater detail in Chapter 9.) Never place a photographic emulsion in direct contact with the framing glass or Plexiglas. Fluctuations in temperature and humidity could cause the gelatin to adhere to the glass or alter its surface characteristics. Never allow a light source to be placed inside a frame or case or in close proximity to the front of the glass. Such illumination can result in the acceleration of fading of certain color prints, in a build-up of heat inside the frame, and in the photochemical degradation of certain types of photographs. For the same reasons, never hang a photograph in direct sunlight.

Aside from aesthetic considerations, photographs are framed primarily for security reasons. Security framing is required for extremely fragile objects that cannot tolerate fluctuating environmental conditions, in which case a sealed microenvironment may be required (discussed in Chapter 9), and for protection of objects on display. Most objects framed for display, particularly if they are to travel, should be glazed with Plexiglas. Although it may scratch easily, it is virtually unbreakable, saving the photograph from the hazards of broken glass. Also, Rohm and Haas manufactures a variety of Plexiglas that incorporates an ultra-violet filter that removes a substantial portion of the damaging ultra-violet radiation that may fall on a framed photograph. However, Plexiglas should not be used for objects heavily overpainted with chalks, pastels, and charcoal, as Plexiglas tends to hold static charges that can pull loosely attached image particles from the surface of the photograph. Framed materials, if well sealed, are protected from air-borne pollutants, dust, dirt, etc.

As discussed in the previous section, only high quality, neutral pH boards should be used for matting and framing. The matted work must be separated from the stiff, outside backing board by a layer of archival-quality mount board. Outside backing boards for frames should be made from a sturdy, relatively stable material, such as FoamCor or Coroplast (also known as Cor-X, Polycore, Correx, Plasticore, and Corflute). Corrugated cardboard or wooden panels should not be used and photographs should not be framed in wooden frames unless the wood is well sealed and does not contact the photograph directly.

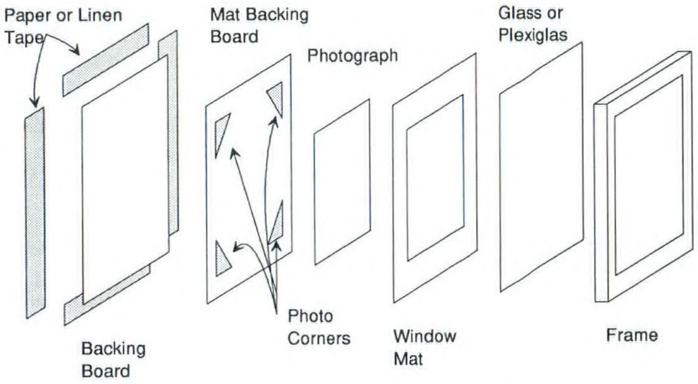


Fig. 7.42: Components of a standard frame including mat and backing.

The Conservation Center for Art and Historic Artifacts in Philadelphia, Pennsylvania, has devised a "sealed package" for photographs intended for display (Norris, 1983). The package consists of a piece of ultra-violet filtering Plexiglas at the front, the matted object, and polyester film at the reverse. All edges are sealed with a sturdy polyester film tape. The assembly is placed into a frame. The package is intended to buffer the photograph against drastic fluctuations in relative humidity. Additionally, it keeps out air-borne particulate matter and gaseous pollution.

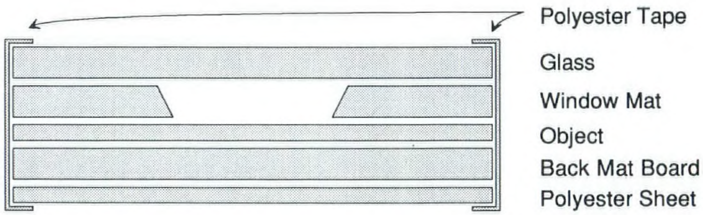


Fig. 7.43: Sealed package for exhibition items. The matted item is sandwiched between ultra-violet absorbing Plexiglas (on top) and polyester film (Mylar) on the bottom. The package is sealed around the edges using polyester tape.

Although the frames for a number of items may require a consistent choice of materials and methods, it is important to assess the specific requirements of individual photographs in the group to be displayed. Mounted historical photographs may be quite warped, requiring a special mat design. Composite photographs that include three-dimensional objects may require an unconventional frame, such as a shadow box. Those images that are highly susceptible to fading may require a curtain over the frame, to be lifted for viewing. Security precautions may dictate the method of display presentation of rare daguerreotypes or salted paper prints.

The display of photographs presents additional risks to the life of the image. The photograph conservator can minimize these problems by the judicious choice of materials and methods.

7.17 Treatment of Photographs in Cases

7.17.1 The Case Itself

"Case photographs," as described in Chapter 5, refers to those early photographs that were commonly displayed in decorative cases. Daguerreotypes and ambrotypes were almost never sold without a case, although one finds them loose in collections and antique markets today. Tintypes are sometimes found in cases, as well, although this was generally not their original form of presentation. More often, the inexpensive tintype was placed in a simple paper folder with an inside oval mat cut to frame the portrait. Also, tintypes are often found alongside *cartes-de-visite* in 19th-century family albums. The use of these cases has contributed to the longevity of these fragile images, despite the use of manufacturing materials that may not fit our definition of "archival." However, as objects that have been removed from their cases are more often than not found damaged, considerable protection (from dust, fingerprints, abrasion, water damage, and breakage) would appear to be provided by the case. Because conservators are called upon to treat the case as well as the image inside it, discussions of both are included in this chapter.

The decorative daguerreotype and ambrotype cases were a convention inherited by the earliest photographers from the profession supplanted by photography: miniature portrait painting. Indeed, many daguerreotypists were previously miniature painters, so it is not surprising that standard plate sizes, and the use of cases that fit those sizes, carried over into the new studio art of photography. (It should be pointed out that daguerreotypes were also presented in watchcases, lockets, and brooches.)

The earliest daguerreotypes were enclosed in papier mâché cases, or wooden cases covered with paper, cloth or leather, and embossed with various designs from nature or mythology. (Gutta percha, a rubberlike gum from the latex of Southeast Asian sapodilla trees, was also used for cases.) These case designs often play a role in dating the image and identifying the photographer and sitter. European cases were typically lined with silk, while velvet was preferred in the United States. In 1854 an American, Samuel Peck, patented the "Union" case, a thermoplastic made of sawdust and shellac, which was available in about 800 moulded cover designs and was exported widely (Rosenblum, 1984). Peck's patent notice still can be found in many of those cases that survive today. These Union cases became collector's items, which accounts in part for the number of "naked" daguerreotypes for sale today; case collectors bought the case and left the daguerreotype behind, in a display of values that may seem inverted today, when photographic collectors have come to recognize the historical value of the image inside the case.

The components of the encased image can vary, but usually consist of six parts:

1. The image: daguerreotype or ambrotype; less frequently, a tintype.
2. A mat (square, rectangle, oval, or circle), made of thin, embossed and/or bevel-edge brass or, occasionally, heavy paper, which contributes a decorative effect and acts as a spacer between the image and cover glass.
3. A cover glass which sits on the mat.
4. A paper or cloth tape (found primarily on daguerreotypes, rarely on ambrotypes) that binds together and seals the edges of these first three layers. This seal may extend to and cover the verso of the image and may carry inscriptions or printed information useful in identifying and dating the subject and photographer.
5. A thin, often decorative, edge frame of heavy brass foil that binds together the four components listed above.
6. A hinged case into which the assembly is sunk. A small lining cushion of silk or velvet may protrude slightly around the "sandwich." The inside surface of the case, under the cloth lining (silk or velvet), is generally wood, covered on the outside with either plastic (Union case), gutta percha, embossed paper, cloth or leather.

Fig. 7.44: Disassembled ambrotype case.

The most common kinds of damage to cases and image enclosures include broken hinges; broken or missing clasps; faded, worn or lifting velvet or silk; brittle, twisted, and broken brass foil edge frames; broken or unglued paper edge seals; broken or missing cover glasses; and tarnished brass mats or edge frames.

In all of the treatments and repair methods described below, when it is necessary to remove these images from their cases, one must exercise great care. They are often fitted quite tightly into the case. Clumsy attempts to remove them can result in broken glass and damaged plates. Gently slip a fine metal spatula between the brass foil and the side of the case. Apply very light pressure inward and attempt to lift the assembly straight up. Move the spatula around the brass frame gently, prying upwards. A Teflon-coated spatula will help to reduce the possibility of scratching the brass frame. Once one edge is lifted, it can be lifted out with a gloved hand. A small suction cup (for hanging objects on windows) can also be used. Attach the suction cup to the cover glass and gently lift the assembly from the case.

Case Conservation

The repair of the decorative photographic case follows basic bookbinding techniques. The object is given a thorough dusting and all accumulations of dirt are removed. Fabric linings can be re-adhered with a very small quantity of very dry paste. The hinge can be re-attached by lifting the break edges and inserting a strip of heavy paper (or pared leather, for leather cases). Cover designs of embossed paper or leather can be re-attached with a small quantity of PVA emulsion such as Jade 403. Broken or cracked cover glasses should be replaced with modern borosilicate window glass. The brass foil frame that binds the edge of the picture assembly can be repaired using small pieces of brass foil and an epoxy adhesive. Japanese tissue and a PVA adhesive may suffice for this job.

When curatorial permission has been given for breaking original seals on daguerreotypes (found occasionally on ambrotypes and tintypes) or when the seal is no longer intact, the components of the assembly can be repaired. Tape residues can be removed from the verso of the plate with swabs dampened in distilled water. (Solvents may be required.) Brass mats, if corroded, can be treated by using a sharpened applicator stick or pin tool (under a microscope) to gently dislodge the corrosion products. Complete scrubbing and polishing of the mat is generally unnecessary. Once the corrosion products have been removed, the mat surface can be wiped with alcohol and gently buffed. If corrosion is extensive, a light coating of microcrystalline wax can be applied to the top of the mat. (The wax must be completely dry before the mat is placed next to the image.) The image plate, brass mat, and cover glass may then be resealed as outlined in Section 7.17.2, Daguerreotype Conservation. The repaired brass foil frame is placed around the sealed package, and the entire assembly is returned to the repaired case.

Some normally encased images (daguerreotypes and ambrotypes) that are found without cases require the construction of special display cases or boxes. One such design, developed by Alice Swan, is illustrated in Section 7.15 (Figure 7.41). Other protective storage boxes, similar to those used to house rare books and photographic albums, can be constructed by the conservator (Brown, 1982).

7.17.2 Daguerreotype Conservation

The most fragile photographic image layer is found on the daguerreotype. In its earliest form it was an image made on a silver-coated copper plate that was sensitized in iodine vapor, exposed in a camera (for from five to sixty minutes), and "developed" by exposure to mercury fumes (which formed on the polished silver plate particles of silver amalgam that comprise the actual image that rests on the silver) (Daguerre, 1839a,1839b; Gernsheim, 1968; Newhall, 1961,1967). Later, chemical accelerators and other variations on and improvements to Daguerre's procedure (including the use of special lenses, reflecting mirrors, blue window glass, and white face powder) made it possible to shorten the required exposure time, so that the portraits could be made by the daguerreotype process. By the summer of 1840, less than a year after the August 1839 announcement of Daguerre's invention, Dr. John W. Draper had made a daguerreotype portrait of his sister, Dorothy Catherine Draper, with an exposure time of only 65 seconds.

Fig. 7.45: Daguerreotype image obscured by tarnishing.

This Draper image is considered to be the earliest surviving daguerreotype portrait and by 1933 was sufficiently tarnished that it was taken to a restorer for cleaning (Enyeart, 1970). In 1938 Robert Taft, the author of the first American history of photography, provided an appendix to his book in which he gave instruction on the cleaning of daguerreotypes with a 1% solution of potassium cyanide in distilled water (Taft, 1938). Taft reproduced a 1933 copy photograph of the Draper portrait in his book, with the added caption, "The image has now (1937) disappeared from the daguerreotype" (Taft, 1938). The image had disappeared from the plate in an unsuccessful attempt to clean it using the cyanide cleaning formula and illustrates the unreliability of this cleaning method. In 1970, a staff member at the Missouri Historical Society, which owns the image, made the image visible again using a combination of thiourea and phosphoric acid in a solution derived from those used in commercial silver tarnish-removal fluids (Field, n.d.; Enyeart, 1970). Although this cleaning method may make daguerreotypes "look" better, the thiourea method is now considered, by some, to be destructive to the quality and long-term stability of the daguerreotype image (Pobboravsky, 1978). This story therefore raises certain important practical and ethical issues about daguerreotype cleaning.

The study of daguerreotype deterioration and conservation is in its infancy, although analyses and prescriptions have been made for more than a century (anon., 1877). Little is known about the responses of silver and silver amalgam to various chemical and physical treatments. The mechanism by which the silver amalgam adheres to the silver plate is not yet well understood. Approximately 10 years ago the thiourea/phosphoric acid method was performed in this laboratory on a number of daguerreotypes from the Documentary Art and Photography Division collection of the National Archives of Canada with, from a purely visual examination, very favorable results. Ten years after treatment, they continue in good condition. Amidst growing scepticism about all tarnish removal treatments for daguerreotypes, the use of this treatment was discontinued in 1981 and will not be revived until further research has been conducted in this important area.

Several new cleaning methods for daguerreotypes have been recommended since 1981 including Plasma Reduction (Daniels, 1981), Physical Sputtering (Barger, 1982) and Electrocleaning (Barger, 1986). As none of these methods have been attempted or thoroughly investigated in this lab, and questions remain regarding their long-term effects, they will not be discussed. However, the student should survey the literature mentioned above in order to gain familiarity with the history of daguerreotype cleaning.

There is no reliable estimate of the number of daguerreotypes existing in private and public collections today. In reality, they may number only in the thousands or tens of thousands, but even if there were millions of these earliest photographic images around, each one would have a special historical value that would make its sacrifice questionable from an ethical standpoint.

A photograph conservator should be familiar with the existing research in the various areas of photograph conservation, (e.g., Daniels, 1981; Daniels et al., 1979; Swan, 1981). As you become familiar with the literature of the field, you will find a great range in the quality and reliability of the research and findings. The conservator must approach each new pronouncement with initial caution, until the findings have been independently verified. This is particularly true when research methods are questionable.

Although we cannot say that there are no expendable daguerreotypes, we can say that an experiment that will alter or destroy a daguerreotype is worth the cost only if that experiment is designed and carried out in such a way that the results are reliable and render essential information. In the absence of studies that use laboratory-produced step wedges, carefully controlled accelerated aging tests, and before-and-after treatment evaluations comparing, for example, before-and-after scanning electron photomicrographs of the same exact area on the original image, conservators must be wary of claims that various treatments do not cause a deterioration of the image quality and that treatments enhance long-term stability. As with other chemical and physical treatments, any alteration in the morphology of the silver amalgam or plate silver raises ethical questions about the integrity of the original object.

Cleaning Daguerreotypes

Tarnished daguerreotypes show black and iridescent stains. Scratches, abrasions, fingerprints, and the outline of the protective mat are also found along with an accumulation of dust, dirt, and other accretions on the plate. Occasionally, the copper plate has been exposed beneath the plate's silver coating. The best treatment a conservator can give to a daguerreotype is to place it in sealed protective housing and leave it alone. If a daguerreotype is very dirty, a gentle jet of forced air can be used to blow off loose dust, or it can be dusted gently with a very soft brush. Daguerreotypes should only be "vacuumed" using light suction, without touching the surface. Some conservators immerse and rock the image gently in a distilled water bath followed by an ethanol rinse and then drying with forced warm air. This procedure should be done quickly and smooth latex gloves worn at all times. Considerable surface dirt and accretions can be removed in this manner; however, it is recommended for extreme cases only as the dusting procedures mentioned above should suffice in most instances. Also, handcolored daguerreotypes, found from the early 1840s on, cannot be treated in aqueous solutions as most coloring media is water soluble. Dusting of colored images should also be approached judiciously, as some coloring media could be physically dislodged.

The glass cover on the daguerreotype may be dirty and can be cleaned with distilled water. Broken cover glasses can be replaced with contemporary (borosilicate) window glass. Original unbroken cover glasses should not be routinely replaced, as the composition of the glass may someday provide essential identifying information. Likewise, original paper and cloth seals may contain inscriptions, labels, and imprints that provide clues to the identification of the image and photographer. When the original seal is intact, it should not be opened without curatorial consultation.

Studies of daguerreotype surfaces have shown in many cases the presence of crystallite forms composed of sodium or potassium plus smaller amounts of calcium, sulfur, and lead, the closest source of which is the cover glass (Swan, 1981). Plates containing these spots viewed in conjunction with their cover glasses, in many cases, show a correlation between the spots on the plates and pits in the interior surface of the cover glass. If it is decided to reuse the original glass, it should be first well washed, thoroughly dried, and then reversed. Remember that the presence of the original cover glasses on daguerreotypes has served to protect these fragile images for nearly 150 years; without this protection, few would remain for study in collections today.

The fact that so many daguerreotypes survive today in reasonably good condition is the result of the packaging of the plate. Air-borne pollutants and poor storage materials can result in a rapid deterioration of the image. Consequently, resealing dismantled daguerreotypes is mandatory. Stable, non-reactive materials and a minimal amount of moisture in the adhesive is required. Some conservators recommend placing an interlayer between the brass mat that sits directly on the daguerreotype surface and the daguerreotype itself. As this interlayer sits directly on the plate, it must be completely non-reactive. A pure fibre paper such as 3-mm Whatman filter paper or an uncoated pure polyester such as Dupont Mylar Type D can be used. The image plate, interlayer, mat, and cover glass are sealed around the edges, using thin strips of heavy Japanese tissue and a PVA emulsion such as Jade 403. Daguerreotypes found without cases can be housed as described in Section 7.15 (Figure 7.41).

7.17.3 Ambrotype and Tintype Conservation

Ambrotypes

In 1850, the English engraver Frederick Scott Archer published his method for sensitizing a collodion emulsion. Photographers and inventors had been looking for a way to free the negative image from the paper graininess inherent in the calotype process. Archer provided a grain-free and colorless emulsion, with the added advantage of a decreased exposure time if the negative was exposed and developed while the collodion emulsion remained moist (Rosenblum, 1984). One would expect that photographers would immediately use the new wet collodion process to make photographs on paper. But just as the first daguerreotypes imitated the studio conventions, handcoloring, and formats inherited from the miniature portrait painters, the first widespread application of the wet collodion process was to make unique (nonrepeatable) images on glass, preferred because they were much cheaper to produce than the daguerreotypes they imitated. In 1854, James Ambrose Cutting patented the ambrotype process in the United States. The process remained popular until the late 1850s, when it was eclipsed by the wildly popular mounted miniature albumen photograph, the *carte-de-visite* (also produced from a wet collodion negative, but produced in multiples, unbreakable, and far less expensive than the ambrotype).

The ambrotype process (called "wet collodion positives" in England and Europe) made use of the phenomenon whereby a negative image appears to be positive when viewed against a dark background. A glass plate (in standard daguerreotype plate sizes, to fit standard decorative cases) was coated with the collodion emulsion, sensitized, exposed, and processed. The negative was backed with a black cloth or black lacquer layer to give the appearance of a positive image. It was matted, covered with glass, framed in brass, and slipped into a decorative case, to look like a daguerreotype to the casual viewer. Variations included the painting of black lacquer on the emulsion surface itself, rather than the back side of the glass; the use of black paper as a backing; and the use of a dark-colored glass (often a deep red or brown) as a support for the collodion emulsion.

Ambrotype Conservation

The ambrotype most often suffers from flaking lacquer or damaged backing material. Sometimes the glass plate itself is broken. Tarnish, in the form of bluish discoloration, may be apparent on this silver image. The emulsion layer, often coated with a protective varnish, may be yellowed and cracked. In those ambrotypes that used them, the cover glass may be missing. One can repair or consolidate the black lacquer, repair or replace the dark cloth or paper backing material, and replace broken cover glasses. The emulsion should not be subjected to aqueous or non-aqueous treatments unless careful preliminary tests are made and curatorial approval given. Repairs to the mat, frame, and case follow the procedures described for daguerreotype conservation.

Tintypes

In 1856, Hamilton L. Smith, a professor at Kenyon College in Ohio, patented what came to be called the tintype (first called melainotype and ferrotype), a wet collodion negative supported by a thin sheet of iron (not tin) painted black ("japanned"). Later variations used dark brown lacquer. This was, like the daguerreotype and ambrotype, a unique image. Like the ambrotype, the dark backing on a tintype produces the appearance of a positive image, although it is actually a collodion negative on lacquered iron. These small, unbreakable, inexpensive, and easily transportable images became quite popular and were still made until the 1930s (often at small country fairs). American Civil War soldiers often carried tintype family portraits in their packs and mailed home portraits made in the field by itinerant tintype photographers. The images were muddy, in comparison to the crisper definition of the daguerreotype and ambrotype, but they were the first portrait process to be affordable for ordinary citizens. Although they were usually sold without covers or cases, or in a simple paper folder, tintypes are often found displayed in decorative daguerreotype or ambrotype cases. More often, they may be displayed among the *carte-de-visite* portraits in family albums.

Tintype Conservation

Encased tintypes, and those found in albums, are usually in better condition than loose ones. Tintypes, with their sharp edges, damage each other and gouge other photographs stored with them. They bend easily, which causes the emulsion to crack and flake off, exposing the iron which could eventually corrode. When such treatment does not threaten the integrity of the emulsion, corrosion products can be removed carefully, working with a sharpened applicator stick under a microscope. The emulsions were often varnished to protect them and like other silver images, there may be evidence of discoloration caused by tarnish.

The protective housing case for daguerreotypes, tintypes, and ambrotypes designed by Alice Swan (Figure 7.41) has been modified to protect and support the image, without forcing it flat, causing additional damage. It provides a spacer around the

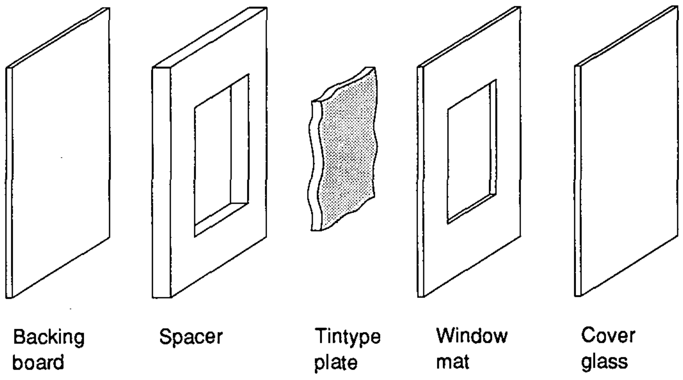


Fig. 7.46: Case designed to accommodate the warpage of a tintype plate.

plate which has the same depth as the warped plate (Figure 7.46). If the tintype is to remain in an accompanying case, repairs to the mat, glass, frame, and case should follow the procedures outlined above in Section 7.17.1, The Case Itself: Case Conservation.

When large numbers of tintypes, or budget constraints, make it impossible to provide separate storage cases for each image, loose tintypes should be stored in heavy paper envelopes of the appropriate size, to protect them from other photographs stored with them. They should not be stored horizontally or beneath other items in boxes, for fear of bending the metal, but should be stored vertically. High humidity levels can cause the exposed iron support to rust, which may cause the emulsion to blister.

7.18 Emulsion Transfer

The process of transferring a photographic emulsion from a deteriorating base, while not taken directly from the repertoire of paper conservation, is somewhat analogous to the dismounting or re-backing of works of art on paper.

The deterioration of early flexible film bases has resulted in the destruction of numerous valuable images. (See Chapter 5 for nitrate and cellulose diacetate film date ranges.) It is a problem that has no perfect solution. Negatives on film bases known to deteriorate can be duplicated before the image quality is eroded. Originals can then be placed in cold storage. If the film base has begun to shrink, a common form of deterioration in cellulose diacetate negatives, no suitable duplicate negative can be made from the buckled, crinkled, and blistered emulsion layer. Nor can such a negative be satisfactorily printed and the print copied photographically. Cellulose nitrate-based materials show chemical decomposition of the film base itself, which in turn deteriorates the emulsion layer. For both nitrate and cellulose diacetate negatives of special importance, where duplication cannot be carried out, emulsion transfer provides a means to save the original emulsion. The long-term stability of transferred emulsions is unknown; however, it is the only means now available to save original film emulsion.

The graphic arts industry has removed gelatin emulsions from their plastic film bases for many years, to facilitate the compilation of composite images such as those found on catalogue pages. The film base is dissolved, using solvents. Both sides of the emulsion are protected and supported by a stripping film and transparent film cement (Grossman, 1980; Reed, 1987). The images are then cut and pieced together as required, eliminating the edge shadows that appear when photographic prints are cut up and pasted together.

Any distortion, dimensional changes, staining, losses, or other alterations of a historical negative emulsion would be unacceptable, from a conservation standpoint. As insurance against the loss of the negative image, prior to attempting any emulsion transfer the best possible print should be made from the negative. After the emulsion has been transferred, the new negative should be duplicated and printed, as additional insurance against degradation of the transferred emulsion, using the sensitometrically controlled methods outlined in Chapter 6.

There are several published procedures for emulsion transfer. The United States National Archives and Records Service published in 1977 a procedure to transfer an emulsion to a temporary support, as a temporary means of obtaining a duplicate negative (Gear, 1977). This procedure was designed for use with diacetate-based ("shrinking base") materials. It involves the use of solvents to dissolve the subbing layer of the film, allowing the emulsion to be floated off the base. The edges of the film ($^1/_{16}$") must be trimmed to allow the solvents to penetrate, because the base itself is insoluble. The subbing layer must be removed entirely; some subbing materials have a tendency to become chalky and opaque upon drying. The emulsion is then sandwiched between two pieces of Mylar and gently squeezed. The moist negative emulsion is duplicated immediately, before it begins to curl off the Mylar as it dries.

A procedure developed by Eastman Kodak is the one most often encountered in published materials (Eastman Kodak, 1982; Reed, 1987). It was developed to deal with both nitrate and, with some variation in procedure, diacetate films. Nitrate-base films are first placed emulsion side down on a piece of glass. Water-proof tape secures the film edges. Scotch Brand polyester film tape No. 850 (silver) or No. 853, $^3/_4$" wide, is recommended and should be burnished along the edges to avoid penetration by the solvents. (It is not necessary to trim the film edges, as the nitrate film base is chemically dissolved in this procedure.) The gelatin anti-curl backing layer is removed, using a concentrated bleach (e.g., Clorox — and other American brands — 5% solution of sodium hypochlorite, etc.). The nitrate base and subbing layer are then dissolved using a strong solvent (2-butanone). All residues must be carefully scraped off of the emulsion underside. Any remaining base material can result in a whitish deposit on the emulsion layer. A soft tissue dipped in solvent can be used to remove any remaining material. Next, the emulsion is carefully removed from the glass leaving the tape attached to the emulsion. Do not attempt to cut the emulsion along the tape edge while it is still attached to the glass as the emulsion may shatter. Once off the glass, the tape can be safely cut from the edges of the emulsion.

A piece of Kodak Roller Transport Clean-up Film or cleared Kodalith Ortho Film is then taped to a piece of glass. Lay the emulsion onto the new base with the top side of the emulsion layer facing up. Using an eye dropper, slowly apply a Kodak Photo-Flo solution (1:10 dilution) to the surface and as it penetrates, the emulsion will relax and lie flat. For the physical protection of the emulsion, cover it with 3M translucent stripping film. The stripping film is first fixed to clear it, washed, and then peeled from its base and laid on top. The entire assembly is then lightly squeegeed, working from the center out using a soft rubber squeegee. Allow the entire assembly to dry completely before removing it from the glass and trimming. The gelatin, both on the new base and the emulsion, will act as the binder to hold the assembly together. As the actual long-term stability of these restored negatives is unknown, densitometrically controlled duplicates should be made as soon as they are dry.

When emulsions are removed from diacetate-base film, the film must be trimmed on all four sides, to allow for solvent penetration. It is not necessary to tape the negative onto glass as it is immersed in the solvent. The subbing layer is dissolved with solvents (acetone or 2-butanone) and the emulsion removed. It is then applied to a new base material (either Kodak Roller Transport Clean-up Film or cleared Kodak Kodalith Ortho film) using the procedure outlined above for nitrate-based materials. The emulsion is protected, as with the nitrate restoration procedure, with 3M translucent stripping film, peeled from its base. A variation of this procedure has been developed, using a non-aqueous alkaloid lacquer to protect the newly mounted emulsion (Ostroff, 1978).

Fig. 7.47: Deteriorated nitrate- and diacetate-base negatives.

The salvaging of historically valuable negatives on deteriorating film bases is one of the most pressing problems found in collections today, because of the need to carry out a duplication or emulsion transfer procedure before the inevitable deterioration has gone too far to save the image. The most practical solution is the development of in-house procedures for negative duplication. However, for small numbers of particularly valuable images, emulsion transfer offers a solution. It is a labor-intensive technique, requiring skill and experience. The unsupported emulsion is extremely vulnerable, particularly in aqueous solutions. The long-term effects of the various solvents and treatments on the gelatin emulsion has received little research attention. Therefore, although photograph conservators should be aware of the procedure, it is recommended only under exceptional circumstances.

7.19 References

Anon. 1877. How to Clean Daguerreotypes. *Practical Photographer* 1(7): 224-225.

Antonacci, J. 1979. *The Repair of Broken Glass Plates.* Project report, Picture Conservation Division, Public Archives of Canada.

Barger, M. Susan, et al. 1982. The Cleaning of Daguerreotypes: 1. Physical Sputter Cleaning, A New Technique. In *American Institute for Conservation of Historic and Artistic Works Preprints of Papers Presented at the Tenth Annual Meeting, Milwaukee, Wisconsin, 26-30 May, 1982,* 9-20. Washington, D.C.: AIC.

Barger, M. Susan, et al. 1986. Cleaning Daguerreotypes. *Studies in Conservation* 31(1): 15-28.

Brown, Margaret R. 1982. *Boxes for the Protection of Rare Books: Their Design and Construction.* National Preservation Office Publication. Washington, D.C.: Library of Congress.

Burgess, Helen, and Season Tse. 1987. *The Use of Enzymes in Paper Conservation.* Paper presented at the A.I.C. Annual Conference. Vancouver. May 20-24.

Corbeil, Marie-Claude. 1989. *Detection of Silver in Painted Photograph Samples.* Canadian Conservation Institute Analytical Report ARS, no. 2766. Ottawa: CCI.

Daniels, V., et al. 1979. Gas Plasma Reactions for the Conservation of Antiquities. *Studies in Conservation* 24(2): 85-92.

Daniels, V. 1981. Plasma Reduction of Silver Tarnish on Daguerreotypes. *Studies in Conservation* 26(2): 45-49.

Daguerre, L.J.M. 1839a. Practical Description of the Process Called the Daguerreotype. Trans. J.F. Frazer. *Journal of the Franklin Institute,* n.s. 24: 303-311.

Daguerre, Louis Jacques Mandé. [1839b] 1971. *Historique et description des procédés du daguerréotype et du diorama. [An Historical and Descriptive Account of the Various Processes of the Daguerreotype and the Diorama.]* [Paris: Susse Frères] Reprint, with introduction by Beaumont Newhall. New York: Winter House.

DeSantis, Pia C. 1983. Some Observations on the Use of Enzymes in Paper Conservation. *Journal of the American Institute for Conservation* 23(1): 7-27.

Dobrusskin, Sebastian. 1989. *Identification, Conservation and Restoration of Colored and Overpainted Photographs.* Project report, Picture Conservation Division, National Archives of Canada.

Down, Jane. 1988. *Report on Adhesive Testing at the Canadian Conservation Institute.* Paper presented at Symposium '88, Canadian Conservation Institute, held at the National Gallery of Canada, September, 1988.

Eastman Kodak Company. 1982. Salvaging Black-and-White Photographic Images; Tranferring a Black-and-White Emulsion Layer from Nitrate- or Early Safety-Base Films to a New Support. *Current Information Summary* (Rochester, N.Y.) 12: 1-2.

Eder, Josef-Maria. [1945, 1972] 1978. *The History of Photography*. Trans. by Edward Epstean. [New York: Columbia University Press]. Reprint: 4th ed. New York: Dover.

Enyeart, J. 1970. Reviving a Daguerreotype. *Photographic Journal* (London), Sept., 338-344.

Field, Ruth K. n.d. *The Missouri Historical Society's Method for the Restoration of Daguerreotypes.* Unpublished manual. n.p.

Gear, J.L., et al. 1977. Film Recovery of Some Deteriorated Black and White Negatives. The *American Archivist* 40(3): 363-368.

Gernsheim, Helmut and Alison. 1968. *L.J.M. Daguerre: The History of the Diorama and the Daguerreotype*. Reprint. New York: Dover.

Grigsby, W. D. 1977. *Photographic Restoration: A Compilation of Information and References.* Term paper. Ryerson Polytechnical Institute, Toronto.

Grossman, J. 1980. Emulsion Stripping: The Bare Facts. *Industrial Photography* 29(1): 22-23.

Kennedy, Nora. 1988. Three French Photograph Conservation Techniques. In *Topics in Photographic Preservation*, 2: 40-49. Washington, D.C.: American Institute for Conservation. Photographic Materials Group.

Keyes, Keiko Mizushima. 1988. Some Practical Methods for the Treatment with Moisture of Moisture-Sensitive Works on Paper. *Symposium '88, Postprints*. Ottawa. Canadian Conservation Institute.(to be published. Summer '91)

Moffatt, Elizabeth and Laver, Marilyn. 1981. *Erasers and Related Dry Cleaning Materials*. Canadian Conservation Institute Analytical Report ARS, no. 1738.

Newhall, Beaumont. 1961. *The Daguerreotype in America*. 3rd rev. ed. New York: Dover Publications.

Newhall, Beaumont. 1967. *Latent Image: The Discovery of Photography*. New York: Doubleday.

Norris, D. H. 1983. The Proper Storage and Display of a Photographic Collection. *The Book and Paper Annual of the AIC* 2: 66-81.

Ostroff, E. 1978. Rescuing Nitrate Negatives. *Museum News* (Washington, D.C.) 57(1): 34-42.

Pearlstein, E.J., et al. 1982. Effects of Eraser Treatment on Paper. *Journal of the American Institute for Conservation*. 22(1): 1-12.

Perron, Johanne. 1989. The Use of FTIR in the Study of Photographic Materials. In *Topics in Photographic Preservation*, 3: 112-122. Washington, D.C.: American Institute for Conservation. Photographic Materials Group.

Pobboravsky, I. 1978. Daguerreotype Preservation: The Problems of Tarnish Removal. *Technology and Conservation*, Summer, 43.

Reed, V. 1987. *Photographic Retouching*. Kodak Publication, no. E-97. Rochester, N.Y.: Eastman Kodak Co.

Rinhart, F. and M. 1975. A Search for Colour. *New Daguerrian Journal* 3(3): 8-12.

Rosenblum, Naomi. 1984. *A World History of Photography*. New York: Abbeville Press.

Smith, Merrily A., et al. 1984. Pressure-Sensitive Tape and Techniques for Its Removal From Paper. *Journal of the American Institute for Conservation* 23(2): 101-113.

Swan, Alice. 1981. Conservation of Photographic Print Collections. *Library Trends* 30(2): 29-39.

Swan, A. 1981. The Preservation of Daguerreotypes. In *American Institute for Conservation of Historic and Artistic Works Preprints of Papers Presented at the Ninth Annual Meeting, Philadelphia, Pennsylvania, 27-31 May 1981*, 164-172. Washington, D.C.: AIC.

Taft, Robert. [1938] 1964. *Photography and the American Scene: A Social History, 1839-1889*. Reprint. New York: Dover Publications.

Vitale, Timothy, and Jane Sugarman. 1989. *Observations on the Drying of Paper and Their Application to Treatment*. Paper presented at the A.I.C. Annual Conference. Cincinnati, Ohio. May 31-June 4.

Volent, Paula. 1989. *Evaluation of Adhesives for Application to Works of Art on Paper by Accelerated Aging*. Paper presented at the A.I.C. Annual Conference. Cincinnati, Ohio. May 31-June 4.

7.20 Supplemental Readings

Anon. 1975. The Lowly Tintype. *British Journal of Photography*, Dec. 26, 1168-1170.

Ball, Cynthia. 1989. *Flattening of Works on Paper*. Research project, Degree Requirement Masters of Art Conservation. Kingston. Queen's University.

Clapp, A. F. 1978. *Curatorial Care of Works of Art on Paper*. Oberlin, Ohio: Intermuseum Conservation Association.

Deschin, J. 1979. Mass Produced in the 19th Century for Pennies a Piece, Tintypes are Still a Collector's Bargain. *Popular Photography*, Dec., 66, 170.

Eastman Kodak Company. 1979. Sensitized Products: Ambrotypes. *Tips* (Rochester, N.Y.) 10(5): 10.

Epstean, E., and J. Tennant. 1934. Daguerreotype in Europe and the United States, 1839-1853. *The Photo-Engravers Bulletin*, Nov., 262-274.

Estabrooke, Edward M. 1878. Practical Ferrotype Process. *The Photographic Rays of Light* **1**(1): 12-13.

Gill, Arthur. 1974. *The Daguerreotype.* Paper presented at The Recognition of Early Photographic Processes, Their Care and Conservation: A Royal Photographic Society Symposium, London.

Gill, Arthur. 1974. The Rise and Fall of the Daguerreotype. *Photographic Journal* (London) **114**(3): 129-131.

Gillet, M., et al. 1986. Glass Plate Negatives: Preservation and Restoration. *Restaurator.* vol. 7 no. 2: 49-80.

Gould, Barbara. 1987. The Removal of Secondary Supports from Works of Art on Paper. *The Book and Paper Group Annual.* 6: Washington: A.I.C.: 52-64.

Hannavy, J. 1978. The Magnificent Ambrotypes. *British Journal of Photography* **123**(8): 153-155.

Heighway, W. 1879. The Ferrotype. *Practical Photographer* **3**(7): 686-688.

Katcher, Philip. 1978. How to Date an Image from Its Mat. *Photographic Society of America Journal* **44**(8): 26.

Keefe, L.E., and D. Inch. 1984. *The Life of a Photograph.* Boston: Focal Press.

Levenson, G.I.P. 1978. Correspondence on restoration of shrunken sheet film. Sept. 29.

Lothrop, E.S., Jr. 1973. The Old Ways Dead? Not on Your Tintype! *Popular Photography* **36**: 111-112.

Reed, V. 1978. *Emulsion Stripping.* Report. Rochester, N.Y.: Eastman Kodak Co.

Reed, V. 1981. How to Work Restoration Magic on Wrinkled Negatives. *PhotographiConservation* **3**(4): 4-6.

Rinhart, F. and M. 1969. *American Miniature Case Art.* New York: Barnes and Co.

Rinhart, F. and M. 1981. *The American Daguerreotype.* Athens, Ga.: University of Georgia Press.

Rudisill, R. 1971. *Mirror Image: The Influence of the Daguerreotype on American Society.* Albuquerque: University of New Mexico Press.

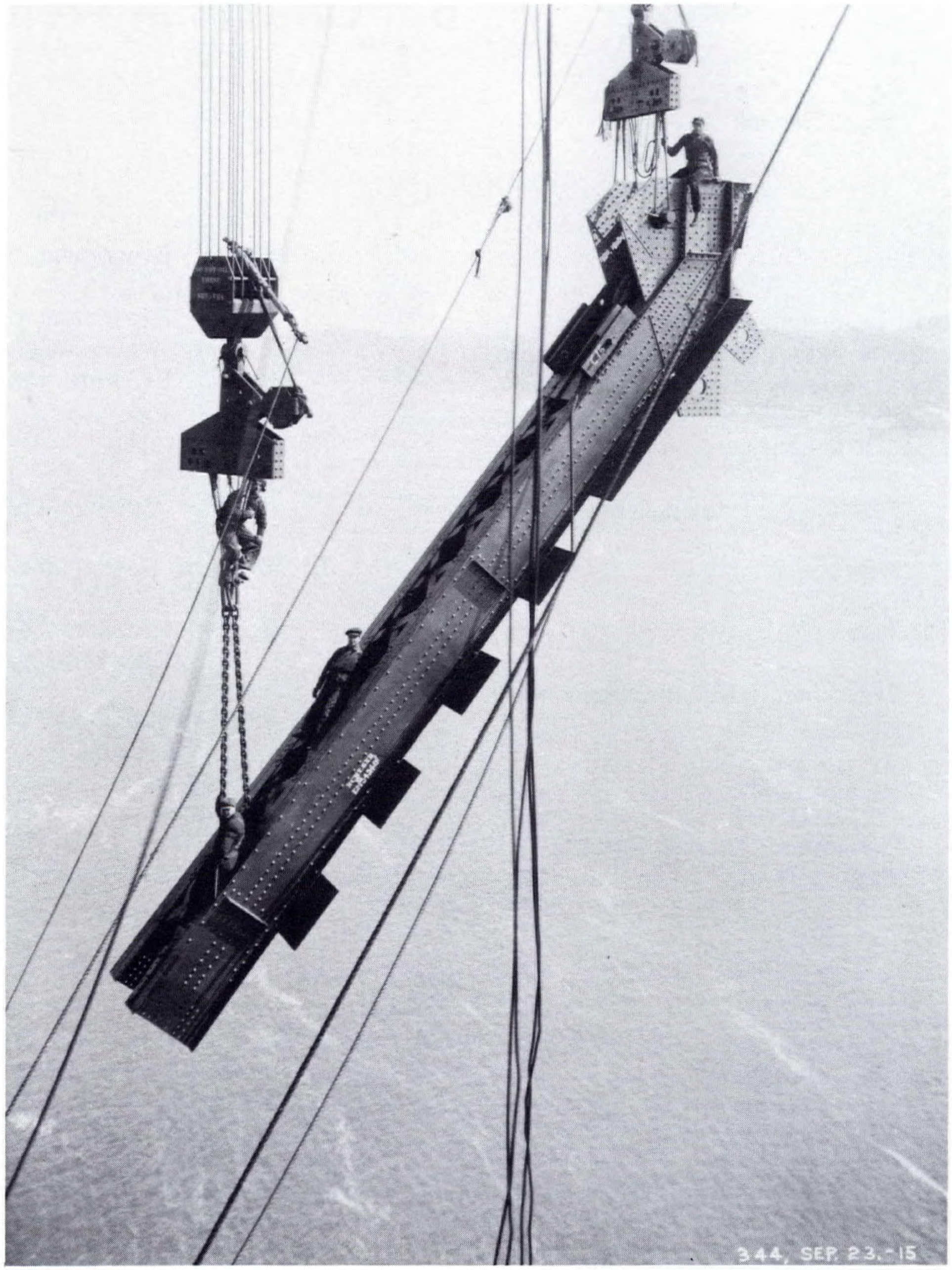
Scharf, A. 1975. *Pioneers of Photography.* New York: Harry Abrams.

Smith, M.A. 1981. *Matting and Hinging of Works of Art on Paper.* National Preservation Office Publication. Washington, D.C.: Library of Congress.

Swan, Alice. 1978. Conservation Treatments for Photographs: A Review of Some of the Problems, Treatments and Practices. *Image* **21**(2): 24-13.

Swan, A., et al. 1979. Daguerreotypes: A Study of the Plates and the Process. *Scanning Electron Microscopy* **11**(1): pages unknown.

Construction of the Quebec Bridge. Quebec City, Quebec. 1915. Eugene M. Finn. Contemporary print from copy negative of original print. National Archives of Canada/PA-172691.



8 Chemical Treatments

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8.1 Introduction

The chemical treatment of a deteriorated photographic image is a controversial issue among conservators, photographers, dealers, and collectors. Little is known about the effects of various chemical treatments on a silver photographic image. How significant are the changes to the integrity of the piece? Does the potential loss through continuing deterioration of historically valuable images justify the risks involved in many chemical treatments and the altering of the morphology of the silver grain? One might argue a convincing case in favor of chemical treatments in terms of *recovering* valuable documentary information. In the case of fine art photographs and rare documentary images few, if any, curators would approve a treatment that may alter the substance, if not the appearance, of the piece. The distinction here is made on the basis of the original artist's or creator's intentions. This is not so much at issue in the case of many photographs, for example, those produced by a news agency, where often little, if any, artistic intention is involved. Nonetheless no valuable or irreplaceable print or negative should undergo the chemical treatments described here unless the proper curatorial decisions have been made. *If a decision has been made* to chemically treat an image then some preliminary steps should be followed:

1. The negative should be duplicated or the print copied prior to treatment (see Chapter 6).

2. If a border of the print or negative can be clipped, then this section may undergo testing (i.e., put through the procedure) to see if the emulsion can withstand the treatment. However, the student is warned that even if positive results are obtained, a chemical treatment may not be successful and the image may be damaged or destroyed.

Historically significant archival collections too often face the problems associated with holdings that number in the thousands or even millions of images. These problems include less than optimum storage conditions, a lack of funding, and staff shortages that prevent the institution from adequately cataloguing and preserving all the images, let alone carrying out restoration treatments on each picture in the collection. The inevitable result is that many images will deteriorate. In the future, if safe and effective chemical treatments have been devised that are appropriate for large collections, these deteriorated images may be recovered. Considerably more research is required in the area of chemical restoration before the procedures introduced here can be recommended for use on a large scale.

The need for more research exists in spite of a wealth of procedures and formulae published in numerous journals and manuals throughout the history of photography. Most of these have their origin in the desire of the photographer to improve an image by correcting errors in either exposure or development. They are legitimate tools in the hands of the creator of that image. However, there is a conspicuous lack of published data indicating the effectiveness of chemical treatments. Caution is therefore advised when adopting and applying procedures described in the older literature. Some procedures appear to have been copied from writer to writer by another without actually having been performed and evaluated. One example is a formula by P. W. Eddingfield, quoted by E. Stenger and traced by him to an article published in *Photographische Industrie* in 1914. Eddingfield is mentioned there as the author of a paper that is not clearly identified. His formula suggests that 85 grams of sodium sulfate and 57 grams of sodium carbonate be dissolved in 115 mL of water. Stenger adds the comment that such "highly concentrated solutions probably can be prepared only by strongly heating the mixture." One may assume that he did not attempt this, for it is impossible to prepare the above solution. A second example is equally illustrative. Recently M. Hansch published a formula for the re-toning of old printing-out papers in a gold salt solution that, he writes, was recommended to him by E. Stenger some 60 years ago. Stenger had published the same formula in his own book, in which he quotes two literature references from 1912. One is in *Camera Craft*, the other in *Photographische Chronik*. From these references the formula can be traced back to 1893 when it is quoted in the *American Journal of Photography*. One H. *Sandaurek* is given as the author of that formula, but without reference. Finally, the *Photographic Reference Book* printed exactly the same procedure in 1906, this time naming the author H. *Laudaurek*, who is said to have received a silver medal in 1888 from the Vienna Photographic Society. The formula and instructions for its use are the same in all citations, but reports on practical results are missing completely. The original contribution originates from Heinrich Jandaurek and was published in 1889 in Eder's *Jahrbuch für Photographie und Reproduktionstechik.*

Chemical treatments are categorized under the headings of *intensification, reduction, harmonization, bleach and redevelopment, stain removal,* and various *cleaning solutions used on daguerreotypes.* (We discuss the cleaning of daguerreotypes in Chapter 7.) Several treatments have been suggested for use in the restoration of historical photographs. In this chapter these techniques are explored in the experiments that follow. For some of the experiments, naturally deteriorated negatives or prints are required that show silver sheens or colloidal silver stains or yellowing due to poor processing and/or oxidizing chemicals. Although such deteriorated photographs may not be available, the experiments may be performed with contemporary samples that have been subjected to sulfide or peroxide fuming (see Section 10.1.4). The peroxide treatment can produce silver sheens readily on prints and negatives, and sulfide fuming will result in yellowing. Poorly processed prints that have been subjected to peroxide fuming or high temperature and humidity conditions will also result in good experimental samples. Using the above samples, however, will likely produce different results than would be expected with naturally aged prints.

8.2 Chemical Treatments for Silver Gelatin Photographs: Intensification, Reduction, and Bleach and Redevelopment

All chemical restoration treatments carried out on silver gelatin photographs affect the original image silver morphology in some way. Many different formulations and mechanisms exist for adding density to an image, for removing density from an image, or for converting a chemically deteriorated silver image back to elemental silver. Basically, chemical treatments can be classified into one of the following categories:

Intensification works by depositing more elementary silver or another metal onto the existing image or by converting some or all the image silver to dark colored and more dense compounds. In the latter case, complexes are formed with metals or organic compounds, which results in the increase in density. The addition of certain dyes can also be used to increase the density.

Reduction involves the removal of image silver. In general, the image silver is partially converted to a soluble salt such as a silver halide (soluble in thiosulfate) or silver ferrocyanide and is subsequently removed.

Harmonization is essentially a combination of intensification and reduction. The negative is bleached in a chromium containing bleach and then developed in a slow-acting developer until the D-min and mid-tone areas are fully developed. The negative is then immediately placed in fresh fixer, which removes some of the as yet undeveloped image silver salts from the high density areas. The harmonization process adds density to low-density areas and removes it from high-density areas.

Bleach and redevelopment bleaches the silver image along with any products of deterioration, in whatever state they may be present, into silver halides. The halides are then reduced back into elementary silver by development.

There are certain factors that must be considered before deciding on the use of a chemical treatment. The outcome of these factors may outweigh the improved appearance of the photographic image.

1. The essential properties of the original image must be maintained, namely:
   a. grain structure
   b. resolution
   c. image tone or hue
   d. surface properties
   e. highlight detail
   f. physical integrity
2. The permanence of the resultant image must be maintained or enhanced.
3. Stain formation, potentially caused by the chemicals used in the treatment, must not occur.
4. The treatment must not be damaging to the binding agent or the support material (Hendriks, 1984).

The photograph conservator must be able to ensure control of these factors before recommending a particular treatment.

It should be stressed at this point that many of the chemicals used in the treatments described here should be handled with respect. Solutions should not come in contact with the skin. Avoid dipping hands or fingers in solutions. Suitable rubber gloves are recommended. The weighing-out of reagents should also be performed carefully, with dust masks being used wherever appropriate. When the possibility of toxic fumes is present, experiments should be performed in a fumehood. Eyes should also be adequately protected where splashing is possible. Wearing a lab coat is recommended whenever handling chemicals. Observe carefully the warnings on reagent bottle labels and refer to Material Safety Data Sheets prior to handling a chemical.

8.3 Silver Gelatin Materials

In 1871 R.L. Maddox published some experiments in which he used silver bromide in gelatin as the light-sensitive substance. Shortly afterwards, silver gelatin photographic materials were introduced commercially in 1878 in the form of glass plate negatives. Although gelatin was known for its durability and stability, its use before this time was limited to sizing for paper. By the turn of the century, silver gelatin photographic materials were the most commonly used and available photographic materials on the market. With the introduction of flexible film bases and multiple exposure roll films, the amateur photographic market burgeoned. Consequently, over the last 100 years, the number of photographs produced has been astronomical and the vast majority of these images are silver gelatin. Many of the earliest examples still exhibit a perfectly intact gelatin emulsion. Because of this large number, investigations into chemical restoration techniques have centered on gelatin materials. Intensification, reduction, and bleach and redevelopment treatments have been developed for silver gelatin materials, but the effect of these treatments on gelatin requires considerable scrutiny.

In any treatment, care must be taken since gelatin is not indestructible. Anyone who has experimented with chemical treatments on gelatin photographs has observed how fragile the emulsion layer can be. Unfavorable environmental storage conditions may weaken a gelatin layer; prolonged immersion in a variety of chemical solutions of different pH levels, can destroy the gelatin emulsion. The emulsion's ability to withstand both wet and dry abrasion, high temperatures, varying pH levels, and prolonged immersion in aqueous solutions are all physical properties that can be tested in the lab. Other properties of gelatin can be monitored through the use of more elaborate equipment.

8.3.1 Tests for the Properties of Gelatin

A number of tests have been developed in order to assess the effect of various factors such as processing solutions, temperature, and relative humidity on the stability of gelatin layers. The tests can be divided into three groups:

1. Accelerated aging tests of photographic specimens, followed by quantitative tests such as tensile strength, elongation, and dimensional changes.

2. Chemical analysis before and after a treatment, such as those using an amino acid analyser.

3. Monitoring of physical properties. The measurable properties of gelatin include

    a. bloom strength,
    b. gel strength, and
    c. viscosity.

    The measurable properties of coated gelatin layers include

    a. melting point,
    b. scratch resistance,
    c. resistance to abrasion during processing ("mushiness"), and
    d. swelling.

Accelerated aging studies are carried out on all testing materials to determine if a treatment has somehow altered the long-term stability of the image. Chemical analysis is extremely time consuming and too complex to be carried out in a standard conservation laboratory, particularly in view of the large number of samples that may need to be analysed. Chemical changes can, however, be implied by physical changes, such as color shifts as determined by a densitometer reading or the change in a sample's ability to withstand scratches.

In our Photograph Conservation Laboratory, four main destructive tests are used to assess the effects of chemical solutions and environmental conditions on gelatin emulsions:

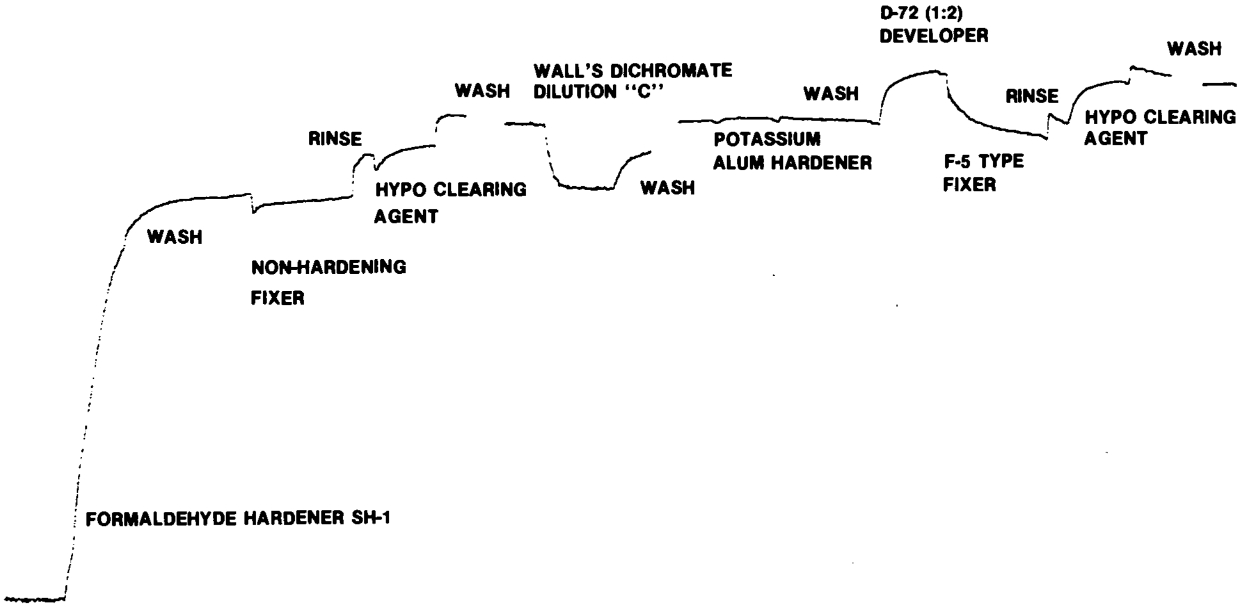


Fig. 8.1: A swellcurve illustrating the swelling and de-swelling of the gelatin layer of a photographic emulsion as it is immersed in various solutions. (The horizontal axis represents time while the vertical axis represents the amount of swelling.)

Melting point: Samples are immersed in a salt solution in test tubes, which are then suspended in a salt solution bath. The temperature of the bath is monitored by a thermometer. The melting point of the photographic emulsion is the temperature where a change in the emulsion structure first occurs (e.g., blistering). ANSI Standard PH4.11-1981 describes the entire procedure.

Scratch resistance: This test measures the hardness of an emulsion by moving a sapphire stylus under a given load across the sample until visible scratches are observed. This is a comparative test, with the resistance being expressed in grams. ANSI Standard PH1.37-1983 describes this procedure.

Wet abrasion: The processing solution or distilled water provides the additional variable of wetness. A weighted arm is dragged across the surface of the sample. Wet abrasion is measured according to the weight on the arm. ANSI Standard PH4.35-1982 describes this procedure.

Swelling: Swelling of a gelatin emulsion sample is measured by a swellmeter. This instrument was designed in 1972 by Green and Levenson (Green, 1972) and measures the swelling and de-swelling of the gelatin layer as a photographic sample is immersed in various chemical solutions. The results are plotted on a line chart recorder. A sample of a swellcurve produced in our lab is given in Figure 8.1.

The application of the results acquired from the above tests is very important in the comparison of products from different manufacturers and historical and contemporary materials, as well as chemically treated and untreated photographic samples. Past and present examinations have generated a good deal of information on the behavior of photographic gelatin. In fact, through the tests described it was determined that a crucial aspect in most chemical treatments of photographic samples is the need for pre-hardeners, which increase the physical stability of the gelatin layer so that it can withstand such treatments.

8.3.2 Pre-Hardeners

As mentioned previously, an important aspect when considering chemical treatments is the effect of such treatments on the binding medium or, in this case, the gelatin. The gelatin must not be weakened or irreversibly damaged in any way as a result of the treatments.

Gelatin takes on water and swells (Sheppard, 1927). This will continue until, at a high degree of swelling, the gelatin layer will break up. Therefore, the more the gelatin swells, the weaker it becomes. Thus, to establish a treatment procedure that can virtually guarantee no harm to the gelatin or support layer, we investigated the use of hardeners at various stages of several chemical restoration treatments. By soaking print and film samples,

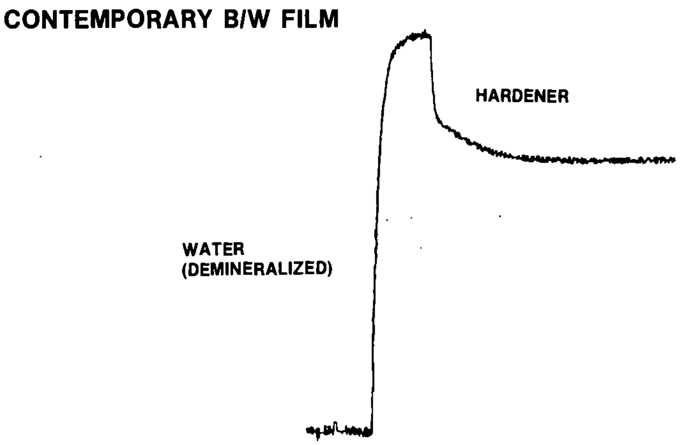


Fig. 8.2: A swellcurve of the gelatin layer of a contemporary black-and-white film indicating the effect of a hardener on the swelling of the gelatin layer.

some hardened and some not, in water at various pH levels and through the use of swellmeter testing (Hendriks, 1985), it was confirmed that hardeners do tend to protect the gelatin by suppressing its swelling as shown in Figure 8.2.

Many bleach and redevelopment formulas and various other chemical treatments require that the photograph be immersed in aqueous solutions for prolonged periods of time. A Formalin hardening bath is then recommended for use before pretreatment washing and fixing of the image.

Some hardeners are also known to wash out in running water. This requires that hardeners be used more than once during prolonged treatments. Hardeners come in various pH levels and with a variety of components. The active hardening component can be metal salts, such as chrome alum, or organic compounds, such as formaldehyde. The suitability of a particular hardener depends to a certain degree on the nature of the solutions preceding and following the hardening bath and the nature of the photographic material itself.

With the inclusion of hardening baths in chemical treatment procedures, gelatin emulsions are more stable, allowing for more in-depth investigations of the other aspects of chemical treatments for photographs.

8.4 Intensification

Originally, the technique of intensification was developed to allow photographers to modify their own negatives so that suitable prints could be made. Certain variables such as the uncertainty in photographic equipment and the lack of exposure latitude in photographic materials made intensification a fairly common occurrence. However, improvements in photographic equipment and negative materials have reduced the need for intensification. Accordingly, photographic papers are now available in many different grades so that imperfect negatives can still be printed satisfactorily, without altering the original negative. Thus, the process of intensification found another application, mainly the restoration of faded historical pictures. The retrieval of historically valuable information that would otherwise be lost is a convincing argument in favor of the use of intensification. Yet, some key points must be considered, namely:

1. Color shift in the image.
2. The possibility of the result not being satisfactory.
3. The preservation of the density range.

Also, conservators should consider carefully the ethical questions that are raised by intensification carried out by anyone other than the original photographer. Using intensification to enhance the market value of a historical print is generally considered unethical. It should be noted that the photographic image is irreversibly affected by intensification.

There are three classes of silver image intensifiers (Haist, 1979):

Proportional intensifiers build up densities proportionate to the amount of existing silver in the image. The increase in density is a percentage of the existing silver, which means that more density will be added to the high density areas, because there was more silver there to begin with. Although density is also being added to the low density areas, contrast is increased, giving the image a greater tonal range.

Super-proportional intensifiers build up density only in the existing high density areas, also effectively increasing image contrast. Low density areas are unaffected by the intensifying action. This is because of the solvent action of these intensifiers, which keeps the densities relatively unchanged.

Sub-proportional intensifiers build up densities only in the existing low density areas or areas containing little image silver. Sub-proportional intensification may be caused by the intensifying action being stopped before the action is complete.

The intensification of a silver image can be accomplished in several different ways (Haist, 1979):

1. *The deposition of silver onto existing image silver.* Silver intensification deposits additional silver onto existing image silver. Silver intensifiers are proportional intensifiers depositing in both the high and low density areas and they result in an image that is as permanent as an unintensified silver image. This type of intensifier is unique in that it does not alter image color. The solutions used must be unstable enough to precipitate silver out of solution and yet stable enough that non-image areas are not coated.

2. *The deposition of other metals such as chromium, mercury, uranium, copper, or lead onto existing image silver.* Chromium and mercury intensifiers are by far the most common.
   Chromium intensification is the intensification most often used today by photographers. It is essentially proportional and is carried out by bleaching the silver image in a potassium dichromate/hydrochloric acid bath and then redeveloping it in a low sulfite developer. (Hydrobromic acid can be substituted for the hydrochloric acid; chromic acid with sodium or potassium chloride can also be used as a bleach bath.) During the bleaching stage, part of the image silver is converted to silver chloride and a chromium compound is deposited on the remaining image silver. During redevelopment, the silver chloride is reduced back to the metallic silver. The end result is an intensified image consisting of metallic silver and a chromium compound. The process can be repeated several times to increase the amount of chromium deposited and thereby increase the intensification.

Mercury intensification is one of the oldest and most toxic procedures. Depending on the redevelopment procedure used, the result is a much higher degree of intensification than with other solutions and a considerable increase in graininess. Mercury-intensified images are generally not very stable and fade unless subsequent treatment reduces the mercury to either a metallic state or a sulfide. The intensification process involves bleaching the silver image in mercuric chloride, iodide or bromide, until all black image silver is turned white. The bleached image is then treated in a second solution resulting in the formation of metallic silver plus a deposit of mercury metal or a mercury compound providing a high degree of intensification. The most common redevelopment solutions are sodium sulfite; an ordinary non-staining developer; ammonia; or Monckhoven's intensifier (potassium cyanide saturated with silver nitrate).

3. *The existing image silver can be converted to another compound that is denser than the metallic silver.*
   Quinone thiosulfuric acid intensifier converts the existing image silver to a denser silver salt. The solution is intended primarily for medium to high-speed negative materials (i.e., coarser grain materials) and is one of the strongest single solution intensifiers available. This method of intensification appears to act by means of oxidation of the silver image followed by the formation of a silver salt or complex of hydroquinone thiosulfuric acid. The salt is quite dark (Muehler, 1945) and results in an image that is brown. The intensified image is grainy and not totally permanent. However, under proper storage conditions it should last for several years.

4. *The formation of dyes that reinforce existing image silver.*
   Dye toning involves treating the existing image silver in a bleach or mordant bath which affects the surface of the silver grains enabling dyes to adhere to them. In one formulation, the surface of the image silver is converted to cuprous thiocyanate and silver thiocyanate and these compounds provide the route to adhesion of the dye to the existing silver. The three dyes employed in one formula (the Lietz dye toning formula) are Methylene Blue, Rhodamine S, and Neophosphine. The dyes absorb certain wavelengths of light, increasing the light-stopping ability of the negative.

8.4.1 Experiment 1: Kodak Chromium Intensifier In-4

Purpose

To observe the effects of Kodak's Chromium Intensifier In-4 on contemporary film samples.

Materials and Apparatus

- Kodak Plus-X Pan Professional Film, 4" × 5"
- chemicals for Kodak Chromium Intensifier In-4:
  - potassium dichromate
  - hydrochloric acid (37%)
- Kodak fixer
- Kodak Hypo Clearing Agent
- exposure template from Experiment 1: 4.2.1
- prepared Kodak Curve Plotting Graph Paper from Experiment 2: 4.2.2
- print washer
- Kodak Photo-Flo
- sensitometer with 2.0 neutral density dichroic filter
- transmission densitometer
- Hope 152 Black-and-White Film Processor
- light microscope
- 6 darkroom trays, 5" × 7"
- chemicals for
  - Kodak D-72 developer
  - Kodak Special Hardener SH-1

Procedure

CAUTION:
Formaldehyde is a suspected carcinogen. Use only with adequate ventilation, preferably in a fumehood, and avoid skin contact. Dichromates are also suspected carcinogens and strong oxidizers. Care in handling for all forms of the chemical is stressed.

1. Turn on the Hope 152 processor and allow it to come to working temperature.

2. Place a 2.0 neutral density dichroic filter (approx.) in place in the sensitometer. Place the exposure template from Experiment 1: 4.2.1 on the exposure plane of the sensitometer. *In total darkness*, expose six sheets of Kodak Plus-X Film in the sensitometer. Label these samples.

3. Process three of the film samples in the Hope 152 processor: one at 50% base speed; one at 30% base speed; and one at 70% base speed. Take visual density readings of the three samples and plot the characteristic curves. Determine the gamma of the straight-line portion for each sample. All that is required is a well-exposed and developed negative of average contrast (gamma of 0.8 to 1.0) with a density range between 1.60 and 2.00. When the above conditions have been fulfilled, process the other three film samples at the base speed that gave these values.

4. Take visual and tricolor density readings of all steps of the step tablet on the three correctly exposed samples. Record and average the visual readings of the three samples. On a piece of calibrated graph paper, draw the characteristic curve, using the averaged values. Under the light microscope, read and record the resolution target values.

5. Prepare the following solutions:

Kodak Chromium Intensifier In-4 — Stock solution

Distilled water	500 mL
Potassium dichromate (anhydrous)	90.0 grams
Hydrochloric acid (concentrated)	64.0 mL
Distilled water to make	1.0 liter

Kodak Special Hardener SH-1

Distilled water	500 mL
Formaldehyde (37% solution by weight)	10.0 mL
Sodium carbonate (monohydrated)	6.0 grams
Distilled water to make	1.0 liter

Kodak D-72 Developer

Distilled water (50°C)	500 mL
Kodak Elon developing agent	3.0 grams
Sodium sulfite (anhydrous)	45.0 grams
Kodak hydroquinone	12.0 grams
Sodium carbonate (monohydrated)	80.0 grams
Potassium bromide (anhydrous)	2.0 grams
Distilled water to make	1.0 liter

6. Begin the intensification procedure by first hardening the negative in the Kodak Special Hardener SH-1 for three minutes. Follow this by a one-minute wash in a print washer and five minutes of fixing in the Kodak fixer. Wash for one minute, and treat in a hypo clearing bath for three minutes. This is followed by a 20-minute wash.

7. Dilute the Chromium Intensifier In-4 stock solution 1:10 with distilled water. Immerse the sample completely in the solution and bleach it thoroughly at room temperature until all black image silver is gone. Wash the sample for five minutes. Redevelop (two to three minutes) the image in the Kodak D-72 developer (diluted 1:2) in normal room light. Once the image is fully redeveloped, rinse in water for one minute and then fix in Kodak fixer for five minutes. Rinse once again in water for one minute and treat the sample in a hypo clearing agent for three minutes. Finally, wash for 20 minutes, rinse in Kodak Photo-Flo for 30 seconds and hang to dry.

   In all solutions constant and gentle agitation should be applied; a rocker table would be helpful in this regard.

8. When dry, take visual and tricolor readings of the samples. Average the visual readings for all three samples and draw the characteristic curve on the same sheet of graph paper as the non-intensified image curve.

9. Read the resolution targets under the light microscope and compare them to the non-intensified image.

Analysis

Examine the various effects of the chromium intensifier on the original negative. Consider changes in gamma, resolution, density values and the corresponding change in the shape of the characteristic curve. Also observe visual characteristics such as image tone and graininess. Examine the tricolor density readings before and after treatment and comment on how they reflect any changes in image tone.

Question

1. Judging from the results, what kind of intensifier is the Kodak Chromium Intensifier In-4?

8.5 Reduction

Photographic reduction is a chemical treatment that involves the actual removal of silver from an image, thus making it useful in the restoration of overexposed and/or overdeveloped negatives as well as fogged negatives. Reduction is similar to intensification in that it was also developed as a technique to allow early photographers to modify their own negatives. However, with the availability of modern photographic papers of various contrast grades, this process has lost popularity. A potentially confusing point should be mentioned regarding photographic reduction. Reduction refers to the act of removing silver from the image and not the chemical process involved. The chemical process is an oxidation, where metallic silver is being oxidized to silver ions — a loss of electrons.

Reducers are classified according to the way in which they affect the material being reduced. The four categories are listed below (Wall, 1927; Eastman Kodak Company, 1985):

Subtractive or Cutting Reducers result in an image losing the same quantities of image silver for the various density areas. In other words, a high density area will lose the same amount as a low density area. Therefore, fogged or overexposed images become more useful with this type of reducer.

Proportional Reducers remove image silver proportionally. Each image area loses an equal percentage of silver. Consequently, areas of an image that are very dense will have more silver removed than areas of less density. Gamma and visual contrast are lowered by the action of these reducers and overdevelopment can be corrected.

Super-Proportional Reducers eliminate more image silver from a high density area of a negative than from a low density area, due to the higher activity of the reducer in the denser areas. Overdeveloped negatives in need of highlight density (D-max areas) reduction without affecting detail in the shadow areas (D-min areas) can be corrected this way.

Sub-Proportional Reducers remove more silver from the low density areas of a negative than from the high density areas.

The treatment of a print or negative in a reducing solution should be approached with extreme caution, because it is irreversible and can result in irreparable damage. Hardening the emulsion is very important so that it can withstand the highly acidic reducing baths. Also, all photographic materials to be treated should be properly fixed, as many of the solutions will affect any undissolved silver salts present, along with the image. The emulsion should be thoroughly washed, as residual processing chemicals can result in staining. Grease and retouching media present on the print or negative should be removed before treatment, to allow for even coverage of the reducing bath and even action on the silver. It is essential to pre-soak the photograph to be treated, to ensure even penetration by the solution. It is also important that only one negative at a time is treated and that treatment times should be brief. The negative or print should be monitored at regular intervals of the treatment period. The sample is rinsed in distilled water so that the reducing action is stopped. This is very important since some reducers act very quickly and can easily go beyond the desired amount of reduction. Finally, an image that has been treated must be thoroughly washed to eliminate any possibility of staining over time.

Different types of reducers are sensitive to various factors such as concentration and grain size of the silver particles that make up the photographic image. For example, dilution of a subtractive reducer can effectively change it to a proportional one. As for silver particles, small ones are, as expected, more easily dissolved than large ones as a result of their larger surface-area-to-volume ratio. Thus, it is essential to be completely familiar with all the characteristics of the material being treated so that the desired reduction effects can be produced.

The use of reducers on especially valuable historical material is not recommended. The extent of the action is extremely difficult to monitor and, as we have said, there is no way to reverse the action. As indicated in the introduction to this chapter, a convincing case may be presented for the use of reducers to retrieve photographic information that would otherwise be lost. For example, surface stains can be removed from an image , uncovering photographic details beneath it. However, this must be a fully informed curatorial decision.

Several treatments for historic materials have been proposed that act as reducers. The Ammonium Hypo Reducer and the Edith Weyde formula (iodine in alcohol) are designed to remove from negatives the silver surface sheen, which can obscure detail and add density. The C. Fischer formula is designed to selectively remove colloidal silver, which is yellow and disfigures the image. These formulas and one for a typical reducer are examined in the four experiments that follow.

8.5.1 Experiment 2: Kodak Farmer's Reducer R-4a

Purpose

To observe the effects of Kodak Farmer's Reducer R-4a on contemporary film samples.

Introduction

In 1884 E. Howard Farmer first published his reducer formula and it quickly became the most widely used reducer. In fact, it is likely the oldest reducer still in use today and is commercially available as Kodak Farmer's Reducer (R-4a). This reducer exhibits the property or varying action depending upon the amount of components present in solution as well as the silver grain size in the image. As previously mentioned, these factors may change the R-4a formula, which behaves as a subtractive reducer, to one that may show proportional reducer characteristics.

The action of the Farmer's Reducer involves the combined action of two compounds, ferricyanide and thiosulfate. Initially, the ferricyanide reacts with the metallic image silver to produce silver ferrocyanide, which is an insoluble compound in water. The silver ferrocyanide is made soluble by reaction with sodium or ammonium thiosulfate and is subsequently removed from the remaining image.

Materials and Apparatus

- 3 sheets of Kodak Plus-X Pan Professional Film, 4" × 5"
- exposure template from Experiment 1: 4.2.1
- prepared Kodak Curve Plotting Graph Paper from Experiment 2: 4.2.2
- sensitometer with 2.0 neutral density dichroic filter
- transmission densitometer
- print washer
- Hope 152 Black-and-White Film Processor
- light microscope
- chemicals for Kodak Farmer's Reducer (R-4a)
- Kodak fixer
- Kodak Hypo Clearing Agent
- Kodak Photo-Flo
- Kodak Special Hardener SH-1
- 5 white processing trays, 5" × 7"

Procedure

CAUTION:
Do not allow the ferricyanide solution to come into contact with strong acid or high heat.

1. Allow the Hope 152 film processor to reach operating temperature.

2. Place the exposure template from Experiment 1: 4.2.1 on the exposure plane of the sensitometer. Put the dichroic filter (2.0 neutral density) in place. Expose three sheets of Kodak Plus-X Film. Label the samples.

3. Process the film samples in the Hope 152 processor at whatever base speed was determined as appropriate in Experiment 1: 8.4.1.

4. Take visual and tricolor density readings of each of the three samples. Average the visual density readings and draw the characteristic curve on the prepared Kodak Curve Plotting Graph Paper from Experiment 2: 4.2.2.

5. Using a light microscope, read and record the resolution values from the resolution targets on the exposure modulator.

6. Prepare Kodak Farmer's Reducer R-4a, stock solutions A and B, using the following formulas:

Stock solution A	
Potassium ferricyanide (anhydrous)	37.5 grams
Distilled water to make	500.0 mL
Stock solution B	
Sodium thiosulfate (pentahydrated)	480.0 grams
Distilled water to make	2.0 liters

7. Harden the negative by first placing it in Kodak Special Hardener SH-1 for three minutes. Follow this with a rinse in water in a print washer for one minute and then fix in Kodak fixer for five minutes. Next wash the negative for one minute and then place it in a hypo clearing bath for three minutes. Wash the sample for 20 minutes.

8. Prepare a working solution of Farmer's Reducer using the following formulas:

Stock solution A	30.0 mL
Stock solution B	120.0 mL
Distilled water to make	1.0 liter

First add stock A to stock B, then add water. Use the solution immediately as it decomposes quickly.

9. Place the first film sample in a tray. Immediately after mixing, pour the solution over the negative and apply gentle agitation. A white tray allows the action to be more easily monitored. The degree of reduction is monitored visually, so a close watch is required. Remove the sample from the tray when sufficient reduction has occurred. Record the treatment time. Wash the negative for 1 minute, treat in a hypo clearing bath for 3 minutes, wash for 20 minutes and rinse in Kodak Photo-Flo for 30 seconds. Hang the sample to dry.

10. Repeat steps 7-9 with the second sample, and then with the third sample, one at a time. Use the same treatment time as used on the first sample. Gentle agitation is required when the sample is immersed in the various solutions.

11. Once dry, take visual and tricolor density readings of all three samples. Average the visual readings. Plot the characteristic curve on the same piece of graph paper as that used for the pre-treatment curve.

12. Under the microscope, read and record the resolution values from the resolution targets.

Analysis

Describe the results of reduction with Kodak Farmer's Reducer (R-4a). Consider changes in the characteristic curve such as gamma and areas of density change. Discuss also any change in resolution. Confirm whether or not the R-4a reducer is acting as a subtractive reducer. Comment on any visual changes, as well as the change in the "base plus fog" value.

Question

1. If the R-4a reducer does not act as a subtractive reducer, what information would this give regarding the silver morphology of the sample being treated?

8.5.2 Experiment 3: Ammonium Hypo Reducer

Purpose

To observe the effects of the Ammonium Hypo Reducer on the silvering-out and dichroic fog commonly found on historic silver gelatin negatives.

Fig. 8.3: The appearance of a silver sheen (across the top) on a black-and-white negative when viewed by transmitted light.

Introduction

One of the most common forms of silver photographic image deterioration is silver and silver sulfide staining. By transmitted light, these stains appear yellow, red, purple or grey, and by reflected light appear yellow, brown, hazy grey, and very often as a blue metallic sheen. Figures 8.3 and 8.4 illustrate this effect. These stains can be so disfiguring that they totally obscure the image.

Fig. 8.4: The appearance of the same silver sheen and negative as in Figure 8.3 when viewed by reflected light.

Thus, to retrieve historically valuable information, it may be necessary to chemically treat the photograph. As mentioned earlier in this chapter, chemical treatments represent a threat to the integrity of the object, often altering the morphology of the silver grains. Furthermore, chemical treatments have the potential of causing physical damage to the gelatin or support layer. Extreme caution is advised when attempting to chemically remove stains.

In alkaline fixing solutions, no loss of image density apparently occurs but an acidified fixing bath has been observed as an effective reducer (Henn, 1951). The reducing effect of sodium and ammonium thiosulfate fixing baths has been well known for quite some time (Russell, 1932). Ammonium thiosulfate, generally used as a rapid fixer, has stronger reducing properties than sodium thiosulfate. A photograph left in an acid fixing bath for an extended period is subject to attack by oxygen in the air. The oxygen is dissolved in the acidic fixer and then goes on to cause ionization of the silver particles. The silver ions produced form complexes with thiosulfate and are removed from the emulsion and into the solution. The rate of such a reduction depends on several factors: the pH level, the temperature, the degree of agitation, and the freshness of the solution. Also it is worth repeating that fine grain emulsions are more susceptible to reduction than coarser grain ones.

In 1951, Henn, Crabtree, and Russell first published a formula for an Ammonium Hypo Reducer (Henn, 1951). This solution acts first to remove the ionized and redeposited silver (which has formed a silver sheen on the photograph) and then proceeds to proportionally reduce the silver image. The use of the Ammonium Hypo Reducer is restricted specifically to the reduction of disfiguring silver sheens on the surface of a photograph. As soon as the stain is reduced, the plate or print should be removed from the solution before the image silver begins to be reduced, treated in a hypo clearing bath, and thoroughly washed. A sample result of the removal of the silver sheen is shown in Figure 8.5.

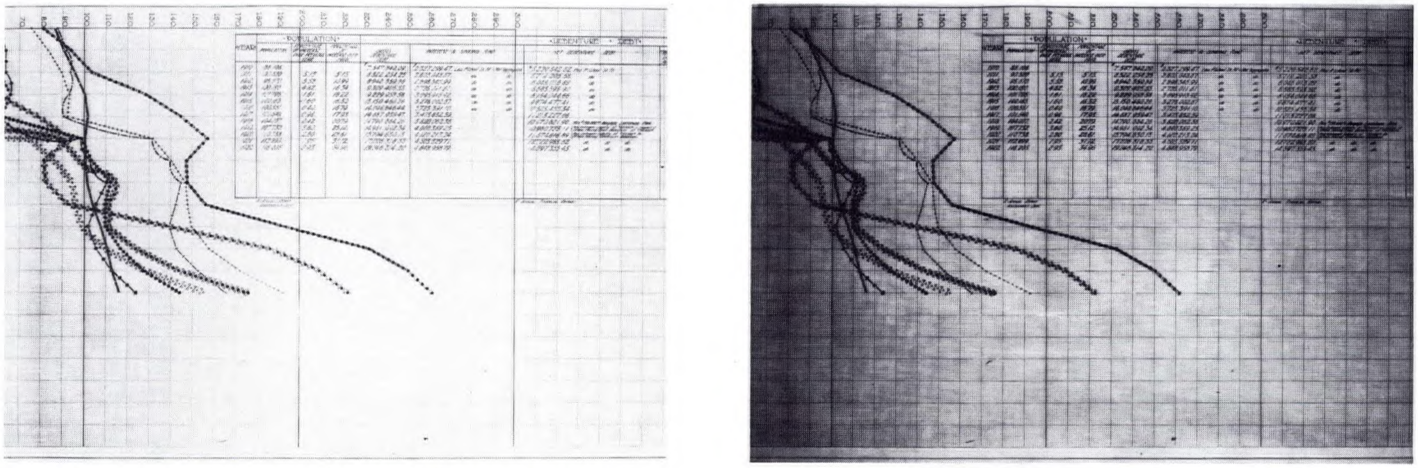


Fig. 8.5: a. A print (prior to treatment) made from a silver gelatin glass plate negative with a silver sheen spread on various portions of the negative. Observe that some of the chart lines have been obscured by the metallic sheen.

b. A print produced identically as the print in (a) (i.e., equivalent exposure and development) but after the negative in (a) was treated in the Ammonium Hypo Reducer. Notice that the chart lines that were previously not visible are very evident after treatment. Also, note the overall increase in the print density.

Henn, Crabtree, and Russell suggest the following Ammonium Hypo Reducer formula for the "removal of silver stains and dichroic fog" (Henn, 1951).

Kodafix (or Kodak Rapid Fixer)	330 mL
Kodak citric acid	15 grams
Distilled water to make	1.0 liter

Materials and Apparatus

- 3 discarded historical negatives with disfiguring silver stains:
    - dichroic fog or
    - silver sheen
- Mylar sleeves
- marking pen (Staedtler-Lumocolor 313)
- hole punch
- chemicals for Ammonium Hypo Reducer
- print washer or tray and siphon
- black-and-white photo paper
- paper developer
- acid stop bath
- Kodak fixer
- Kodak Hypo Clearing Agent
- Kodak Photo-Flo solution
- 6 processing trays
- contact printing frame
- enlarger
- footcandle meter
- fumehood
- transmission densitometer

Procedure

> **CAUTION:**
> During treatment, sulfur dioxide is produced, which not only smells terrible and is toxic, but can affect other sensitized materials. It is important to perform the treatment in a well-ventilated space away from light-sensitive materials preferably under a fumehood.

1. Select three discarded negatives, with disfiguring silver stains and of no value, historical or otherwise. Place each in a Mylar sleeve and, using a marking pencil, mark on the sleeve the exact position of the negative inside the sleeve. Circle a low, medium, and high density area for each negative, numbering them from 1 to 3. Remove the negative from the sleeves. Punch holes in the sleeves inside the three circles drawn on each sleeve. This enables density readings to be taken at exactly the same locations before and after any treatment. Reposition the negative with the image facing the direction in which the holes were punched (i.e. , to avoid scratching of the emulsion due to rough edges) and take visual and tricolor density readings at each of the three circles on each of the three negatives. Record the readings in chart form.

2. Make the best possible contact print from each negative. Record the f-stop, exposure time, and footcandle reading at the paper exposure plane as well as the paper type and contrast grade. Do not burn or dodge to produce better prints. Process each print according to the standard procedure. Use a hypo clearing bath for three minutes after fixing. Wash for 20 minutes.

3. Prepare the Ammonium Hypo Reducer bath, using the following formula. Prepare the solution immediately before use. Discard after using. The solution is reactive and loses potency over time.

Kodak Kodafix diluted 1:3 in distilled water	500 mL
Citric acid (anhydrous)	15 grams

4. Treat the negatives one at a time. Place the negative first into water for approximately one minute to allow the gelatin to swell evenly. Then place the negative into the solution with continuous gentle agitation. Constant observation is necessary so that the negative can be removed from the solution when the stains are sufficiently reduced. Remove the negative periodically to better observe the reducer action.

5. When the stain or sheen has been sufficiently reduced, remove the plate from the solution and record the treatment time. Wash in a print washer for one minute. Treat the negative in a hypo clearing bath for three minutes. Wash for 20 minutes, rinse in Kodak Photo-Flo for 30 seconds, and air dry.

6. When completely dry, position the negatives in the Mylar sleeves. Take tricolor and visual density readings at all three circles on each of the three negatives. Record the results in chart form with the before-treatment readings.

7. Make the best possible print from the negatives following treatment, using exactly the same materials, light levels, exposure times, and processing procedures as used in step 2 of this experiment.

Analysis

Describe the results of the use of the Ammonium Hypo Reducer. Compare changes in the stain before and after treatment by looking at the negatives by transmitted and reflected light.

Questions

1. Comparing the before and after prints, what is the effect of the treatment overall?

2. How successful was the treatment in removing the silver sheen and dichroic fog stains?

3. What is the mechanism of image loss when prints or negatives are left too long in acidic fixers?

8.5.3 Experiment 4: Edith Weyde Formula

Purpose

To observe the effects and evaluate the results of the Weyde iodine/alcohol formula for the removal of surface silver stains.

Introduction

Silver, although classified as a noble metal (i.e., one that is chemically inert), is very reactive to certain chemicals when present in a photographic emulsion. It is particularly affected by oxidizing agents. Such oxidizers have various sources such as the surrounding atmosphere (e.g., automobile emissions), certain residual processing chemicals, adhesives, glues, inks, freshly produced plastic materials, and certain types of paint fumes (Feldman, 1981). These compounds act on the metallic silver that makes up the black-and-white photographic image and produce silver ions. Once the silver ions are formed, they can migrate in all directions within a photographic emulsion, more so under high humidity conditions. Evidence has been presented that silver ions can migrate downward into the baryta layer, giving a silver sulfide imprint of the image in this layer as displayed in Figure 8.6 (Weyde, 1955).

Also, it has been shown that the ions can migrate upward as illustrated in Figure 8.7 (Hendriks, 1988). In this case, accumulation of metallic silver at the surface of the gelatin occurs and a blue metallic sheen is formed. This layer can be very disfiguring and can add considerable density to the area on which it is deposited, obscuring image details (see Figures 8.3 and 8.4).

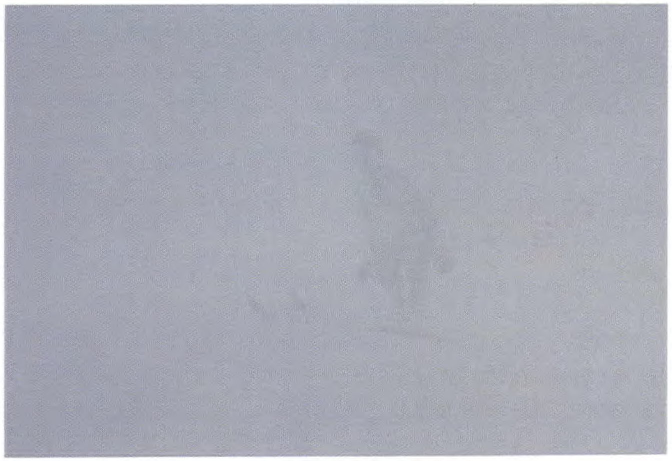


Fig. 8.6: A silver sulfide imprint of a silver image on the baryta layer of the corresponding photograph. The emulsion was stripped so that the imprint could be observed.

Fig. 8.7: A transmission electron micrograph showing the effect of the migration of silver ions towards the top of the gelatin layer of a black-and-white film. Notice the accumulation of metallic silver at and towards the surface of the layer. Magnification 21,500 times.

In addition, silver that has oxidized forms colorless silver salts (Weyde, 1972). These salts, when subjected to certain chemicals, such as sulfur compounds, formaldehyde, and acids, are converted to brown or yellow compounds, which appear as spots on the emulsion (see Figure 8.8).

To restore an image damaged in these particular ways, the photograph conservator can bathe the photograph in a solution of iodine in alcohol. The alcohol must be pure, with absolutely no water present. Water would swell the gelatin, allowing the iodine access to image silver and leading to its eventual loss. The alcohol penetrates the gelatin very slowly in the absence of moisture so that the iodine has access only to the metallic silver on the surface. Thus, the iodine converts the metallic silver on the surface and the yellow spots that are on or near the surface to silver iodide. The negative

Fig. 8.8: Brown spots on a black-and-white photograph due to the formation of colored compounds of silver.

Fig. 8.9: a. A print produced from a negative with a metallic sheen across the top likely caused by the oxidative action of the adhesive of the envelope in which it was stored.

or print is then fixed and washed, which removes the silver halide. Figure 8.9 displays the results of the treatment on a negative. Silver is actually being removed from the image during this treatment making it irreversible. This treatment should be used only after careful consideration. The advantage to this procedure is that the morphology of the image silver is not altered. Only the disfiguring stains are removed.

Fig. 8.9: b. A print exposed and processed identically as the one in Fig. 8.9: (a) after the corresponding negative was treated in iodine and alcohol. Note how effective the treatment was in removing the stain, revealing details that were hidden underneath. Compare the maps hanging on the wall behind the individuals before and after treatment.

Materials and Apparatus

- discarded stained silver gelatin negatives with silver sheen areas
- discarded stained silver gelatin prints with silver sheen areas
- iodine (analytical grade)
- ethyl alcohol (dry)
- Kodak fixer
- Kodak Hypo Clearing Agent
- Kodak Photo-Flo
- acid stop bath
- black-and-white photographic paper
- paper developer
- Mylar sleeves
- hole punch
- marking pen (Staedtler-Lumocolor 313)
- camel's-hair brush
- cotton swabs
- transmission densitometer
- reflection densitometer
- 7 processing trays
- print washer or tray and siphon

Procedure

CAUTION:
It is recommended that this procedure be performed under a fumehood. Alcohol and iodine are irritants. Iodine is toxic by inhalation.

1. Select a discarded photographic negative with considerable metallic sheen on the emulsion surface. In addition, look for one with

disfiguring brown and/or yellow spots on the surface. Label these samples. Place the negatives into Mylar sleeves, mark the exact position of the negative in the sleeve and draw circles on the sleeve at the following three points: mark one low density area, one high density area, and one medium density area. Punch holes in the sleeves at these points, so that transmission density readings may be taken. Re-align the negative in the Mylar with the image facing the direction in which the holes were punched out and measure and record visual and tricolor readings for all three spots to help evaluate the effect of the silver sheen on the density, and the degree to which this image is obscured by these stains.

Follow the procedure of Experiment 3: 8.5.2, steps 2 and 7 in order to visually compare the negatives before and after treatment.

2. With a very soft camel's-hair brush, gently dust the emulsion of the negative to remove dust.

3. Prepare a 1% solution of iodine (analytical grade) in dry ethyl alcohol. Pour the solution in a tray and gently lower the negative into the solution. Apply gentle agitation. Observe the process carefully, so that the negative can be removed as soon as the surface sheen and spots have been converted to yellow silver iodide. This is somewhat difficult to detect visually. Treatment time should be around three minutes. The alcohol will penetrate eventually, so make sure the negative is withdrawn from the solution before the image silver is affected.

4. Place the treated negative immediately into a fresh Kodak fixing bath for five minutes to dissolve the silver iodide formed. Then wash the negative for one minute in water and place it in a hypo clearing bath for three minutes. After a final wash of 20 minutes, the negative is treated in Kodak Photo-Flo for 30 seconds and air dried.

5. Align the negative back in the Mylar sleeve. Take visual and tricolor density readings on the transmission densitometer.

6. Select three reflection print materials that exhibit a metallic sheen on the surface. Label these samples. Select and mark three spots on a Mylar sleeve as in step 1 of the procedure for each print that represent low, medium, and high density areas. Take visual and tricolor density readings at each of the three areas using the reflection densitometer. Record the readings in chart form.

7. Treat print samples 1 and 2 by swabbing the surface with the iodine/alcohol solution. Try to keep the solution from reaching the back of the prints. Fix the prints for five minutes after a brief water rinse of one minute. Wash

thoroughly for 20 minutes after a hypo clearing bath for three minutes. Place flat to air dry.

8. Repeat step 7 with sample 3, completely immersing the sample in the iodine/alcohol solution.

9. Take visual and tricolor density readings at all three marked areas on all three print samples. Record the readings and compare them to the pre-treatment readings.

Analysis

Write a report on the results of the treatment, comparing the swab method to the immersion method, comparing before and after density readings, and making visual comparisons of the stained areas for both negative and positive materials. Compare the results of this method of stain removal with the Ammonium Hypo Reducer method.

Questions

1. How effective was the treatment on silver gelatin reflection print materials?

2. What is the potential mechanism of image destruction of materials in this procedure?

3. Why does the bluish-silver sheen often appear most heavily on the perimeter of the silver gelatin image?

8.5.4 Experiment 5: C. Fischer Formula

Purpose

To investigate the removal of yellow-orange colloidal silver from stained photographic prints using the C. Fischer formula.

Introduction

In addition to the migration noted in Experiment 4: 8.5.3, namely, accumulation of silver in the baryta layer or at the surface of the gelatin, silver ions may

Fig. 8.10: Colloidal silver staining on a black-and-white resin-coated photographic paper.

remain in the emulsion itself. The ions can react with available anions to form stable silver salts or they can be reduced to specks of elemental silver commonly known as colloidal silver. These extremely small fine-grain colloidal silver particles refract light, characteristically appearing yellow, orange, or red. They appear as overall, blotchy yellow stains in high and low density areas, or as bright orange spots on high density areas. Colloidal silver staining is a problem associated to a large extent (but not exclusively) with resin-coated papers (see Figure 8.10), because fibre-base papers tend to absorb much of the migrating silver ions into the baryta layer. In resin-coated papers, the titanium dioxide/polyethylene layer beneath the emulsion acts as a barrier to ions, which then become concentrated in the emulsion.

Fig. 8.11: The results of the use of the C. Fischer formula on a resin-coated paper suffering from yellowing due to colloidal silver formation. On the right is the discolored and untreated print; on the left is the section of the photograph that has been treated.

The C. Fischer formula is designed as a means of removing yellow colloidal silver from stained silver gelatin prints. It comprises thiourea and citric acid in water. This solution acts as a solvent for finely divided silver particles and silver complexes, therefore preferentially removing the yellowing and not the coarser image silver. An illustration of the results possible with this treatment is given in Figure 8.11.

Once again, caution is advised in the use of this treatment as a conservation tool without the proper considerations being discussed.

Materials and Apparatus

- 3 black-and-white print samples with colloidal silver stains (resin-coated or fibre-base)
- marking pen (Staedtler-Lumocolor 313)
- Mylar sleeves
- hole punch
- chemicals for C. Fischer formula:
  - thiourea
  - citric acid (anhydrous)
- print washer
- tray
- reflection densitometer

Procedure

CAUTION:
Thiourea is a suspected human carcinogen. Avoid skin contact.

1. Select three discarded black-and-white photographic prints that exhibit signs of colloidal silver stains. Cut each sample into two equal parts, each half containing representative low, medium, and high density area stains. Label the samples. Place the halves to be treated in Mylar sleeves. Mark their placement in their sleeves. Circle a high, medium, and low density area on each sample. Punch out the holes in the sleeves in these areas and take both visual and tricolor density readings at the three points on each sample.

2. Prepare the C. Fischer solution using the following formula:

Distilled water	200 mL
Thiourea	4 grams
Citric acid (anhydrous)	2 grams

3. Treat the samples one at a time. Begin by placing sample 1 in water for one minute. Then place the sample in the C. Fischer solution and agitate evenly and gently until the stain is reduced. If reduction of non-stained areas becomes evident, remove the sample from the solution immediately. Wash the treated sample for 15 minutes in running water. Lay flat to air dry.

4. Repeat step 3 with samples 2 and 3.

5. Following treatment of all three samples, place them back into their Mylar sleeves and take visual and tricolor density readings at the exact spots from which pre-treatment readings were taken.

Analysis

Write a report on the apparent effects of the treatment considering the visual appearance of the print and any density changes. Note any changes in surface gloss.

Question

1. How would you explain the effect of the treatment on the surface gloss of the prints?

8.6 Harmonization

Harmonization is a process that combines intensification and reduction to build up density in low density areas and reduce the density in high density areas. It is designed to reduce the contrast in negatives that have been overdeveloped. The procedure was first introduced by J.M. Eder in 1881 and entailed bleaching the silver image in an aqueous solution of potassium dichromate, hydrochloric acid, and alum, followed by redevelopment. The image is bleached completely white, thoroughly washed, and then immersed in a slow-acting weak developer, such as a standard Metol/Quinone developer, until the D-min and mid-tone areas are fully developed. The high density areas redevelop rather slowly, while low density areas reappear almost immediately. The surface silver is developed in the high density areas but due to the slow acting nature of the developer, silver halides deeper in the emulsion take a longer time to be developed. The process may be stopped whenever the desired density is reached. The treated object is then rinsed and fixed to remove any silver halides in the high density regions that are left undeveloped. This effectively reduces the image density in these areas. The D-min density area is left unchanged or slightly intensified as a result of the procedure. Such an intensification would further reduce the contrast in the negative being treated.

Because the silver has been altered irreversibly, this treatment again raises ethical questions when used outside the context of retrieving historically valuable information that would not otherwise be accessible.

8.6.1 Experiment 6: Eder's Harmonization

Purpose

To observe the effects of Eder's Harmonization treatment on contemporary film sample step tablets.

Materials and Apparatus

- Kodak Plus-X Pan Professional Film, 4" × 5"
- film processing chemicals
- exposure template from Experiment 1: 4.2.1
- prepared Kodak Curve Plotting Graph Paper from Experiment 2: 4.2.2
- potassium dichromate bleach chemicals
- light microscope
- print washer
- 6 trays, 5" × 7"
- transmission densitometer
- Hope 152 Black-and-White Film Processor
- Kodak D-76 chemicals:
  - Elon
  - Sodium sulfite (anhydrous)
  - Hydroquinone
  - Borax (granular)
- Kodak SH-1 hardening bath
- Kodak fixer
- Kodak Hypo Clearing Agent
- sensitometer with 2.0 neutral density dichroic filter

Procedure

CAUTION:
Dichromates are suspected carcinogens. Handle with suitable rubber gloves and avoid breathing dust.

1. Allow the Hope 152 film processor to come up to operating temperature.

2. Place the exposure template from Experiment 1: 4.2.1 on the exposure plane of the sensitometer. Place the dichroic filter (approximately 2.0 neutral density) in the light path, and expose three sheets of Kodak Plus-X Film. Label the samples.

3. Process the film in the Hope 152 processor at the percent of base speed found to be optimum in Experiment 1: 8.4.1.

4. When processed and dried, take visual and tricolor density readings of all steps of the step tablets on each film sample. Average the visual density readings and draw the characteristic curve on the calibrated graph paper from Experiment 2: 4.2.2.

5. Read and record the resolution target values using the light microscope.

6. Prepare the solutions necessary for the Eder Harmonization formula:

Bleach bath

Distilled water	600 mL
Potassium dichromate (anhydrous)	10 grams
Alum	50 grams
Hydrochloric acid (concentrated 37%)	30 mL
Distilled water to make	1.0 liter

Kodak D-76 Developer

Distilled water (50°C)	500 mL
Kodak Elon developing agent	2 grams
Sodium sulfite (anhydrous)	100 grams
Kodak hydroquinone	5 grams
Kodak borax (granular)	2 grams
Distilled water to make	1.0 liter

Gentle agitation is required in all processing and treatment solutions.

7. Place the film samples first in a hardening bath, Kodak SH-1, for three minutes; wash for one minute, fix in Kodak fixer for five minutes, and then rinse for one minute in water, treat in a hypo clearing bath for three minutes. Wash for 20 minutes.

8. Treat the still-wet film samples in the bleach bath until the image has been completely bleached. Wash in running water for 20 minutes or until the yellow has been removed from the gelatin. Develop the image in weak D-76 developer, diluted 1:4. Once low density areas have completely developed (higher

density areas should be only partially developed), remove the sample. Development should take approximately one minute. Immediately immerse the sample in fresh Kodak fixer (or any hardening fixer). Fix for five minutes, wash for one minute, treat in a hypo clearing bath for three minutes. Wash for 20 minutes. Rinse the samples in Kodak Photo-Flo for 30 seconds and hang to dry.

9. Take visual and tricolor density readings of all sample step tablets. Average the visual density readings and draw the characteristic curve on the same piece of graph paper as the pre-treatment curve.
10. Read and record the alphanumeric resolution target values.

Analysis

Write a report that comments on the change in densities, characteristic curves, and resolution for the before and after harmonization samples.

Questions

1. Judging from your results, how effective is the process of harmonization?
2. Explain how the action of a weak developer enables reduction to occur in the D-max areas of the negative.

8.7 Chemical Restoration

Under certain conditions elemental silver gelatin photographic prints will undergo yellowing, staining, and fading. Oxidizing agents from the atmosphere or other sources (see Section 8.5.3 and Chapter 3) are generally responsible for such effects on the silver image. Residual processing chemicals may also play a role in image degradation. Whatever factors are involved, the end result is prints or negatives that are disfigured in varying degrees. The previous chemical treatments that have been described focused either on the addition of silver, silver compounds or other substances or on the removal of silver from the image in order to restore faded or stained photographic images.

However, chemical restoration procedures are based on the theory that image silver is neither added nor removed during the process. In one case, a bleach and redevelopment sequence is used where all image silver in whichever modification and all silver compounds in whatever form they may be present as products of deterioration are uniformly converted into silver halides, which are then chemically reduced to black elemental silver. In a second case, the conversion of silver compounds back to elemental silver is accomplished by immersing the deteriorated print in a strong chemical reducing bath, such as sodium borohydride. This is a single bath treatment. It requires that the print being treated be free of silver salts in highlight and non-image areas (i.e., that it be thoroughly prefixed and washed before treatment) to prevent staining in these areas.

Chemical restoration procedures seem to be the best chemical treatment for returning faded and stained prints to their original clean black-and-white appearance. However, as in other chemical treatments, ethical questions arise. An image that is only partially deteriorated can provide clues as to what the photograph looked like originally, but a completely faded or heavily sulfided print as in Figure 8.12 does not provide such clues. Thus, it is not known what the print looked like originally and a chemically restored print might vary substantially in image tone, resolution, and other photographic properties. Yet would a retrieval of some kind outweigh these factors? Careful consideration must be given prior to treating a photograph in this way.

8.7.1 Experiment 7: Bleach and Redevelopment

Purpose

To examine the results of a bleach and redevelopment treatment on historic print samples.

Fig. 8.12: A severely yellowed and faded black-and-white photofinishing print from the 1930s. The image is barely visible and much of the detail has been lost.

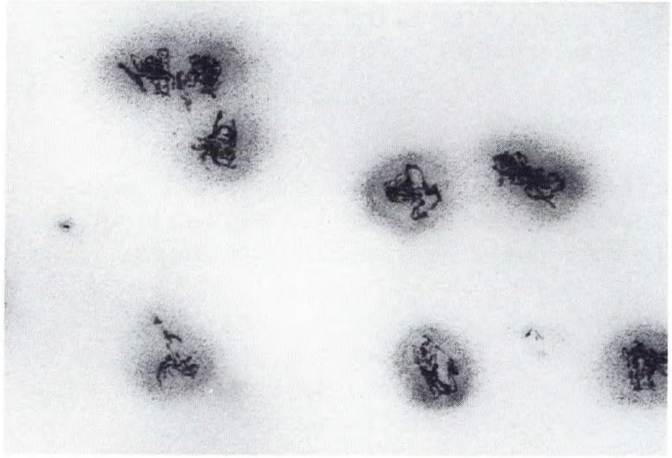


Fig. 8.13: a. Silver grains from a yellowed photofinishing print from the 1930s as viewed using a transmission electron microscope at a magnification of 30,000 times.

Introduction

Bleach and redevelopment experiments have been conducted at the National Archives of Canada for about 10 years. We have gathered a great deal of knowledge about the effects and results of such treatments on historical and contemporary samples. Studies have included aspects such as the examination of changes in the silver morphology using a transmission electron microscope, as a result of the bleach and redevelopment process (see Figure 8.13). From these studies important information on the behavior of the silver grains (i.e., changes in shape and size) has been compiled, allowing for a more accurate interpretation of the process.

Fig. 8.13: b. A transmission electron micrograph of the silver grains from the same photofinishing print as in (a), after a bleach and redevelopment sequence using potassium dichromate and hydrochloric acid as the bleach. Magnification 30,000 times.

In some cases, as shown in Figure 8.14, bleach and redevelopment gives prints with excellent visual appearance, stability, and image detail. In other cases (Figure 8.15), the photograph has degraded beyond the point where this treatment will be of any assistance in recovering historically valuable information and/or producing a visibly desirable print. At this point in the life of the photograph, so much image silver has degraded or migrated out of position or left the emulsion entirely that no known chemical treatment can currently restore such a photograph.

Fig. 8.14: On the left is a yellowed photofinishing print from the 1930s. On the right is the same print after bleach and redevelopment. Notice the clean black-and-white image obtained after the treatment.

Fig. 8.15: On the left is a severely degraded black-and-white photofinishing print from the 1930s. On the right is another print (similar to the one on the left in terms of degradation) after chemical treatment via bleach and redevelopment. A poor image results, illustrating that some prints are beyond chemical restoration procedures.

Several experiments carried out on contemporary test samples in this laboratory have shown that some well-known bleach and redevelopment formulas can result in the total destruction of the photographic emulsion (see Figure 8.16). Staining of the paper base and baryta layer are common occurrences. Extended treatments in solutions of varying pH levels not only can easily destroy the

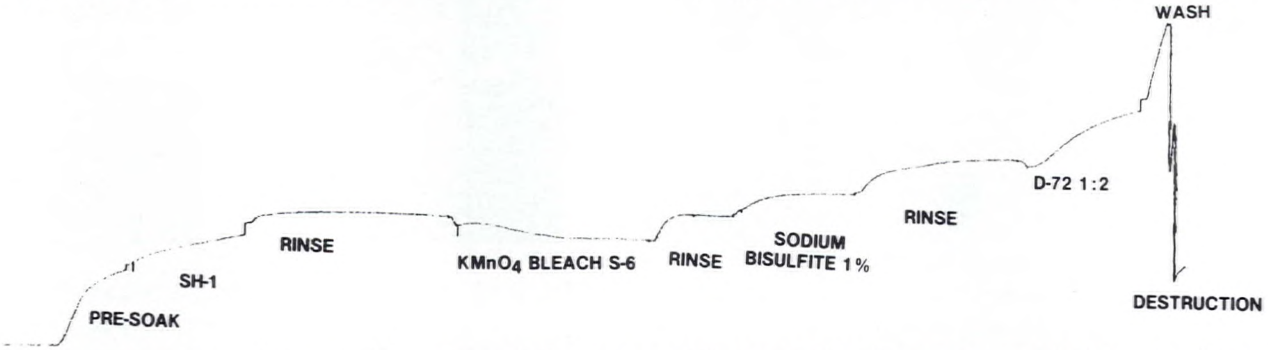


Fig. 8.16: The swelling and de-swelling of a gelatin layer as it is treated in the various solutions of a bleach and redevelopment formula. After development, the gelatin breaks up and is destroyed in the water wash. (Time is represented on the horizontal axis; the amount of swelling on the vertical axis.)

surface gloss of an emulsion but can wipe the gelatin right off the paper base. From these results and observations, certain key variables were examined and are listed below:

1. What bleach will be used?
2. What halide source will be used?
3. Is re-exposure necessary?
4. What developer will be used?
5. Is a pre-fixing treatment necessary?
6. Is a pre-hardening or intermediate hardening treatment necessary?
7. If so, what hardener should be used and at what stage in the process should it be used?

Experimentation in the above areas has resulted in an acceptable chemical restoration treatment. The procedure begins with the use of a pre-hardener as extended aqueous treatments of varying pH are required. This is followed by a reprocessing sequence where pre-fixing occurs to remove any residual silver salts that may cause staining upon redevelopment. A thorough wash and hypo clearing agent treatment come next. The image is then bleached until completely white (or to a very faint yellow) through the use of a potassium dichromate-hydrochloric acid bath. This is followed by a citric acid bath that assists in the removal of the dichromate and shortens the subsequent wash time. After washing, the image is printed-out by using an ultra-violet print box or any other suitable light source until a light to medium density image, purple in color, becomes visible. Redevelopment in Kodak D-72 developer comes next. Fixing in a hardening fixing bath, a rinse, and a hypo clearing bath all precede the final wash. After treatment, the use of a selenium toner is advisable.

Conclusions on the use of bleach and redevelopment have been formulated that will prove useful when considering this treatment.

1. The procedure applies only to silver gelatin prints.
2. The procedure applies only to developing-out papers.
3. The procedure is not recommended for unique, irreplaceable, or particularly valuable prints.
4. Slight changes in image tone and surface gloss appear to be unavoidable.
5. Because we can be guided by data compiled in the course of our previous research, the procedure's success can best be predicted if the manufacturer of the paper and the brand name are known. This allows us to determine the silver halide used and whether the paper is a printing-out paper or developing-out paper.
6. Prints cannot be treated in large batches. Each individual print must undergo at least visual examination prior to any treatment in order to arrive at a preliminary conclusion as to whether a restoration will be successful. Prints can then be grouped into categories expected to produce consistent results. Ideally, there are duplicates that can be used in a possibly destructive test run.

7. Not all prints can be successfully chemically restored.
8. Some prints that were originally poorly fixed and have undergone severe to moderate degradation do not produce good white highlights and non-image areas after chemical restoration.

Materials and Apparatus

- black-and-white photographic paper
- processing chemicals for black-and-white paper
- Kodak photographic step tablet no. 2
- exposure template from Experiment 1: 4.2.1
- 3 historic silver gelatin developed-out prints (discards) with varying degrees of sulfide deterioration
- reflection densitometer
- 3 processing trays
- 8 Pyrex trays
- rocker table
- chemicals for dichromate bleach
- Kodak D-72 developer
- Kodak Special Hardener SH-1
- ANSI Non-Hardening Fixer
- Kodak fixer
- Kodak Sepia Toner
- Kodak Hypo Clearing Agent
- prepared Kodak Curve Plotting Graph Paper
- citric acid solution 5%
- light source for printing-out, e.g., ultra-violet light box
- print washer or tray and siphon arrangement
- Kodak Rapid Selenium Toner

Procedure

CAUTION:
See sections 8.4.1 and 8.2 for safety information.

1. Select a standard black-and-white photographic paper, such as Kodak Azo or Ilford Ilfobrom Galerie. Using exactly the same exposure and developing procedure for each, produce 12 grey scales, using a Kodak photographic step tablet no. 2 as the exposure template. (Alternatively, use an existing exposure template that incorporates a number of step tablets, so that several grey scales can be produced at the same time on the same sheet of paper. This will reduce the chances of introducing processing variables in the completed samples.) Label the samples. Process the samples according to standard processing procedures.

2. Divide the samples into three groups. One group will be maintained untreated as a control group. The second group will be toned prior to bleach and redevelopment, using a sulfur toner (Kodak Sepia Toner). The third group of four samples will be treated in the bleach and redevelopment procedure as is, without prior toning. Take tricolor and visual density readings of all 21 steps on each of the 12 samples. Lightly mark with an HB pencil the group number and the treatment to be given on the back of each sample. Average the visual density readings for group two and

group three. On separate sheets of calibrated graph paper, draw the characteristic curve for the two groups.

3. Select one sample from group two and plot the characteristic curve for the visual density readings and all three tricolor readings so that the four curves are on the same sheet of calibrated graph paper. Select one sample from group three and plot the tricolor and visual curves on another sheet of graph paper.

4. Treat all four samples in group two in Kodak Sepia Toner, following the manufacturer's instructions. Once the toned samples are dried, take visual and tricolor density readings of all 21 steps of each of the four grey scales. Plot the tricolor and visual density curves (four curves) of the same sample used in step 3 on a sheet of calibrated graph paper.

5. Select three historic print samples that are expendable and exhibit moderate to severe signs of fading and staining. Cut each sample into two equal pieces, retaining half as a control. Take visual and tricolor density readings at three areas (one high, one medium, and one low density area) on each of the historic samples to be treated. Use a Mylar overlay as previously described (see Section 8.5.4).

6. Prepare bleach and redevelopment solutions, using the following formulas:

Kodak Special Hardener SH-1

Distilled water	500 mL
Formaldehyde (37% solution)	10 mL
Sodium carbonate (monohydrated)	6 grams
Distilled water to make	1 liter

ANSI Non-Hardening Fixer

Distilled water	600 mL
Sodium thiosulfate (pentahydrate)	250 grams
Sodium sulfite	20 grams
Distilled water to make	1 liter

Dichromate Bleach

Distilled water	700 mL
Potassium dichromate (anhydrous)	20 grams
Hydrochloric acid (concentrated)	20 mL
Distilled water to make	1 liter

Kodak D-72 Developer

Distilled water (50°C)	500 mL
Kodak Elon developing agent	3 grams
Sodium sulfite (anhydrous)	45 grams
Kodak hydroquinone	12 grams
Sodium carbonate (monohydrated)	80 grams
Potassium bromide (anhydrous)	2 grams
Distilled water to make	1 liter

7. Prepare to treat the samples by setting out and organizing the various solutions required. Labelled Pyrex trays on a rocker table is the best arrangement. Samples must be completely immersed in the various solutions with constant and gentle agitation. Print tongs may be used for transferring samples between the various solutions. Washing can be performed either in a print washer or with a tray and siphon arrangement. The following procedure includes 18 steps that must be strictly adhered to:

1. Formalin hardener (Kodak Special SH-1)	3 min.
2. Wash	5 min.
3. ANSI Non-Hardening fixer	5 min.
4. Rinse	1 min.
5. Kodak Hypo Clearing Agent	3 min.
6. Wash	20 min.
7. Dichromate Bleach until bleached.The image should be completely white or a faint yellow with an undiscernible image.	10-20 min. (possibly)
8. Citric acid (5% solution)	10 min. (two baths 5 min. each)
9. Wash	10 min.

10. Print out until medium density appears. The wet sample is placed in a Pyrex tray (containing some water) with the image facing the light source.

CAUTION:
Avoid looking into the ultra-violet light source. Proper ultra-violet goggles must be worn.

11. Developer (Kodak D-72, dil. 1:2)	2 to 3 min.
12. Hardening fixer (Kodak fixer)	5 min.
13. Rinse	1 min.
14. Kodak Hypo Clearing Agent	3 min.
15. Wash	10 min.
16. Kodak Rapid Selenium Toner (1:19)	10 min.
17. Wash	20 min.
18. Air dry	

8. Treat the contemporary samples first, treating the four toned samples from group two together, and then the four samples from group three together.

9. Treat the historic samples separately. Treatments can overlap. However, they should be in the bleach bath separately, so that careful monitoring during bleaching can be maintained.

10. Following treatment, visual and tricolor density readings are taken. All treated contemporary samples should have density readings taken at each of the 21 steps of the grey scales. Density readings of historic samples are taken at the exact spots at which the pre-treatment readings were taken.

11. For the samples used in step 3, plot the tricolor and visual density curves for group two on one sheet of calibrated graph paper and for group three on another sheet.

12. For the individual groups (two and three), average the visual density readings and plot the characteristic curves on the same sheet of graph paper on which pre-treatment curves were plotted.

Analysis

Compare the before and after treatment samples for both groups. Also, compare the results of group two versus group three. Examine variables such as changes in the shape of the characteristic curves for both visual and tricolor readings and image tone differences as well as changes in density. Observe also the changes in density and visual appearance for the historical samples. Comment on the overall success or failure of the restoration.

Questions

1. What differences appear between the treated toned samples and the treated untoned samples? What might possibly account for any differences?

2. For deteriorated historical samples, what factors or causes would render a photograph unrestorable by chemical means?

3. What areas of further investigation do you feel are required before these treatments can be recommended for use?

8.7.2 Experiment 8: Sodium Borohydride Treatment

Purpose

To restore a faded silver photograph using the Sodium Borohydride treatment.

Introduction

Sodium borohydride intensification was designed to intensify faded photographic prints (Haist, 1979). Prints that have faded and yellowed due to oxidation by sulfides, peroxides, and other agents can be reduced back to elemental silver by sodium borohydride. Figure 8.17 presents the result of this treatment on a deteriorated print as described above. In aqueous solution, sodium borohydride

Fig. 8.17: The right side of the print has yellowed and faded over time. The left side is the result of swabbing a sodium borohydride solution over the surface of the print.

acts as a strong reducing agent for silver compounds, after which it decomposes to hydrogen, sodium hydroxide, and boric acid. The residues can be easily removed by a brief water treatment. The solution begins to decompose immediately upon mixing, so working time is limited to between 30 and 60 minutes.

Since little research has been conducted on this restoration procedure, it cannot be recommended for use on valuable, unique, or irreplaceable photographs. The effect on the morphology of the silver grains and the long-term effects of the treatment on the photograph must be examined thoroughly and tested further under laboratory conditions. As with other chemical treatments, under certain conditions, this treatment may be valuable for its use in retrieving from a severely faded photograph information that could be valuable and not available otherwise.

This treatment is recommended only for prints that have been fixed and washed properly, so that all residual silver halides and silver thiosulfates have been removed. Otherwise, sodium boro-

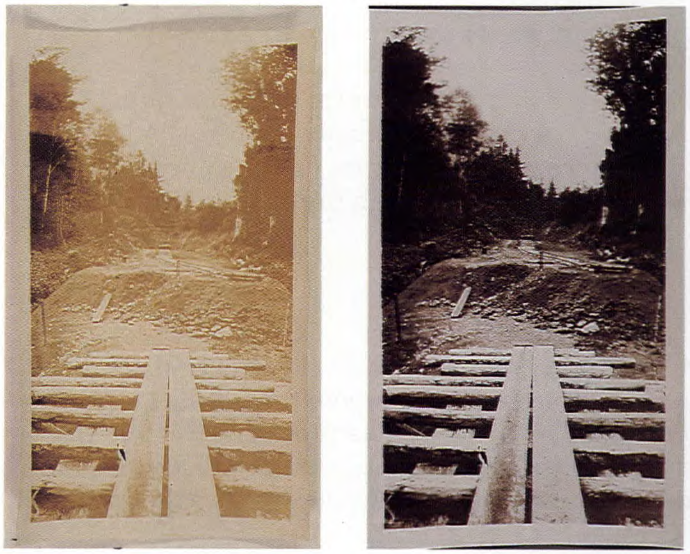


Fig. 8.18: a. A yellowed photofinishing print from the 1930s prior to treatment.

b. The print in (a) after treatment with a sodium borohydride solution. The sample was fixed and washed prior to treatment.

hydride will attack these silver salts, reducing them to metallic silver, which appears as fogging or staining of highlight and non-image areas. The samples in Figures 8.18 and 8.19 clearly indicate the effects described.

Fig. 8.19: a. A yellowed photofinishing print from the 1930s before treatment.

b. The print in (a) after treatment with sodium borohydride and without any pre-treatment such as fixing or washing. In the top right hand corner is the result of a spot test for metallic silver using a cupric chloride bleach. The cupric chloride bleached the area where it was applied, illustrating the need for pre-treatment since the highlights and non-image areas might contain residual silver complexes.

Materials and Apparatus

- 4 faded and discarded silver gelatin prints
- sodium borohydride solution
- distilled water
- print washer
- hole punch
- marking pen (Staedtler-Lumocolor 313)
- Mylar sleeves
- 3 processing trays
- cotton swabs
- blotting paper
- reflection densitometer
- rocker table
- Kodak fixer
- Kodak Hypo Clearing Agent

Procedure

1. Select four faded silver gelatin prints that are of no historic or artistic value (discards). Cut each print into two equal pieces. Select three points on one half of each different print. One area should represent high density with barely discernible detail, one should represent a low density area with barely discernible detail, and the third should be a mid-tone, or medium density, region. Place each sample in a Mylar sleeve and mark its exact position in the sleeve. Circle the three points selected on the Mylar, so that these exact areas can be relocated following treatment with the sodium borohydride solution. Remove the print and punch out the holes on the sleeve.

After re-inserting the print in the sleeve, with the emulsion facing the direction of hole punching, take visual and tricolor density readings at the three points on each of the three different print materials. Record the densities in chart form.

2. Prepare the sodium borohydride solution using the following formula:

Distilled water	1 liter
Sodium borohydride	2 grams

3. Pour the solution into a tray and place the tray on the rocker table. Treat the first print sample in the solution, making sure that total immersion occurs, until no further change is detectable. Make sure that one-half of the print sample is maintained untreated for comparison. Wash the treated sample briefly (approximately five minutes) and air dry.

4. Repeat step 3 with sample two, pre-washing the print for five minutes before proceeding with the full treatment.

5. Repeat step 3 with sample three. First, pre-fix the sample for five minutes in a hardening fixer. Follow this by a one-minute wash, three minutes in a hypo clearing bath, and a 20-minute wash. Then proceed with the treatment.

6. With sample four, simply swab half of the print with the sodium borohydride solution. Try to confine the solution to the emulsion surface only. Repeat the treatment if the results appear streaky or uneven. Swab the surface with distilled water following treatment and allow it to air dry.

7. Take density readings on the treated samples at exactly the same spots where pre-treatment readings were taken. Record the readings in chart form along with the pre-treatment readings.

8. Place both halves of each print sample in the same Mylar sleeve and label as to the treatment received.

Analysis

Write a report on the degree of restoration and the effects of the treatment on each print sample, with regard to change in image tone, any apparent changes in grain size, and the ability of the emulsion to withstand chemical treatment.

Questions

1. Why were certain samples pre-washed or pre-fixed?

2. What were the effects of pre-washing or pre-fixing on these particular samples?

8.8 References

Eastman Kodak Company. 1985. *Black-and-White Processing Using Kodak Chemicals*. Kodak Publication, no. J-1. Rochester, N.Y.: Eastman Kodak Co.

Feldman, Larry H. 1981. Discoloration of Black-and-White Photographic Prints. *Journal of Applied Photographic Engineering* **7**(1): 1-9.

Green, A., and G.I.P. Levenson. 1972. A Practical Swellmeter. *Journal of Photographic Science* **20**: 205-210.

Haist, Grant. 1979. *Modern Photographic Processing*. New York: John Wiley and Sons.

Hendriks, Klaus B., et al. 1984. Properties and Stability of Gelatin Layers in Photographic Materials. *AIC Preprints of Papers Presented at the Twelfth Annual Meeting, Los Angeles, California, 15-20 May, 1984*, 52-62. Washington, D.C.: American Institute for Conservation of Historical and Artistic Works.

Hendriks, Klaus B. 1985. Experiments on the Restoration of Discoloured Black-and-White Photographs in Chemical Solutions. *SPSE Second International Symposium, The Stability and Preservation of Photographic Images : Printing of Transcript Summaries*, 148-163. Springfield, V.A.: Society of Photographic Scientists and Engineers.

Hendriks, Klaus B., and L. Ross. 1988. The Restoration of Discoloured Black-and-White Photographic Images in Chemical Solutions. *AIC Preprints of Papers Presented at the Sixteenth Annual Meeting, New Orleans, Louisiana, June 1-5, 1988*, 99-117. Washington, D.C.: American Institute for Conservation of Historical and Artistic Works.

Henn, R.W., et al. 1951. An Ammonium Hypo Reducer. *Photographic Science and Technique (Journal of the Photographic Society of America)* **17B**(11): 110-113.

Muehler, L.E., and J.I. Crabtree. 1945. A Single Solution Intensifier for Very Weak Negatives. *Journal of the Photographic Society of America* **11**(2): 81-85, 119-122.

Russell, H.D., and J.I. Crabtree. 1932. The Reducing Action of Fixing Baths on the Silver Image. *Journal of the Society of Motion Picture Engineers* **16**: 371-397.

Sheppard, S.E. 1927. Behaviour of Gelatin in the Processing of Motion Picture Film. *Transactions of the Society of Motion Picture Engineers* **11**(32): 707-727.

Wall, E.J. 1927. *Intensification and Reduction: A Critical Resume of All Known Methods*. Boston, Mass.: American Photographic Publishing Co.

Weyde, Edith. 1955. Das Copyrapid-Verfahren der Agfa [The Agfa Copyrapid Process]. *Mitteilungen aus den Forschungs-laboratorien der Agfa* **1**: 262-266.

Weyde, Edith. 1972. A Simple Test to Identify Gases Which Destroy Silver Images. *Photographic Science and Engineering* **16**(4): 283-286.

8.9 Supplemental Readings

ANSI. 1964. *Determining the Melting Point of a Non-support Layer of Films, Plates, and Papers.* ANSI PH4.11-1964 R1981. New York: American National Standards Institute.

ANSI. 1982. *Method for Determining the Resistance of Photographic Films to Abrasion During Processing.* ANSI PH4.35-1982. New York: American National Standards Institute.

ANSI. 1983. *Methods for Determining the Scratch Resistance of Processed Photographic Film.* ANSI PH1.37-1983. New York: American National Standards Institute.

Burgess, Helen D. 1982. The Bleaching Efficiency and Colour Reversion of Three Borohydride Derivatives. *AIC Preprints of Papers Presented at the Tenth Annual Meeting, Milwaukee, Wisconsin, 26-30 May, 1982,* 40-48. Washington, D.C.: American Institute for Conservation of Historical and Artistic Works.

Carroll, John S., ed. 1976. *Photographic Facts and Formulas.* New York: American Photographic Book Publishing Co., 168-189.

Carroll, John S. 1977. *Photographic Lab Handbook,* 4th ed. New York: American Photographic Book Publishing Co., 191-193, 368-379.

Cook, M.M., and J.A. Lander. 1979. Use of Sodium Borohydride to Control Heavy Metal Discharge in the Photographic Industry. *Journal of Applied Photographic Engineering* 5(3): 144-147.

Fischer, C. n.d. Fehlererscheinungen in der Positiv-Abteilung. *Photographische Industrie* **30**: 734-736.

Garwood, A.J. 1907. The Intensification and Reduction of Gelatine Negatives. *American Photography* **1**: 17-25.

Hendriks, Klaus B., et al. 1984. Experiments on the Restoration of Discoloured Black-and-White Photographs in Chemical Solutions. *ICOM Committee for Conservation, 7th Triennial Meeting, Copenhagen, 10-14 September, 1984: Preprints,* **2**: 84.14.34-84.14.37. Paris: International Council of Museums.

Henn, R.W., and J.I. Crabtree. 1947. Sulfide Stain: Its Nature, Cause and Methods of Prevention. *Journal of the Photographic Society of America* **13**: 752-758.

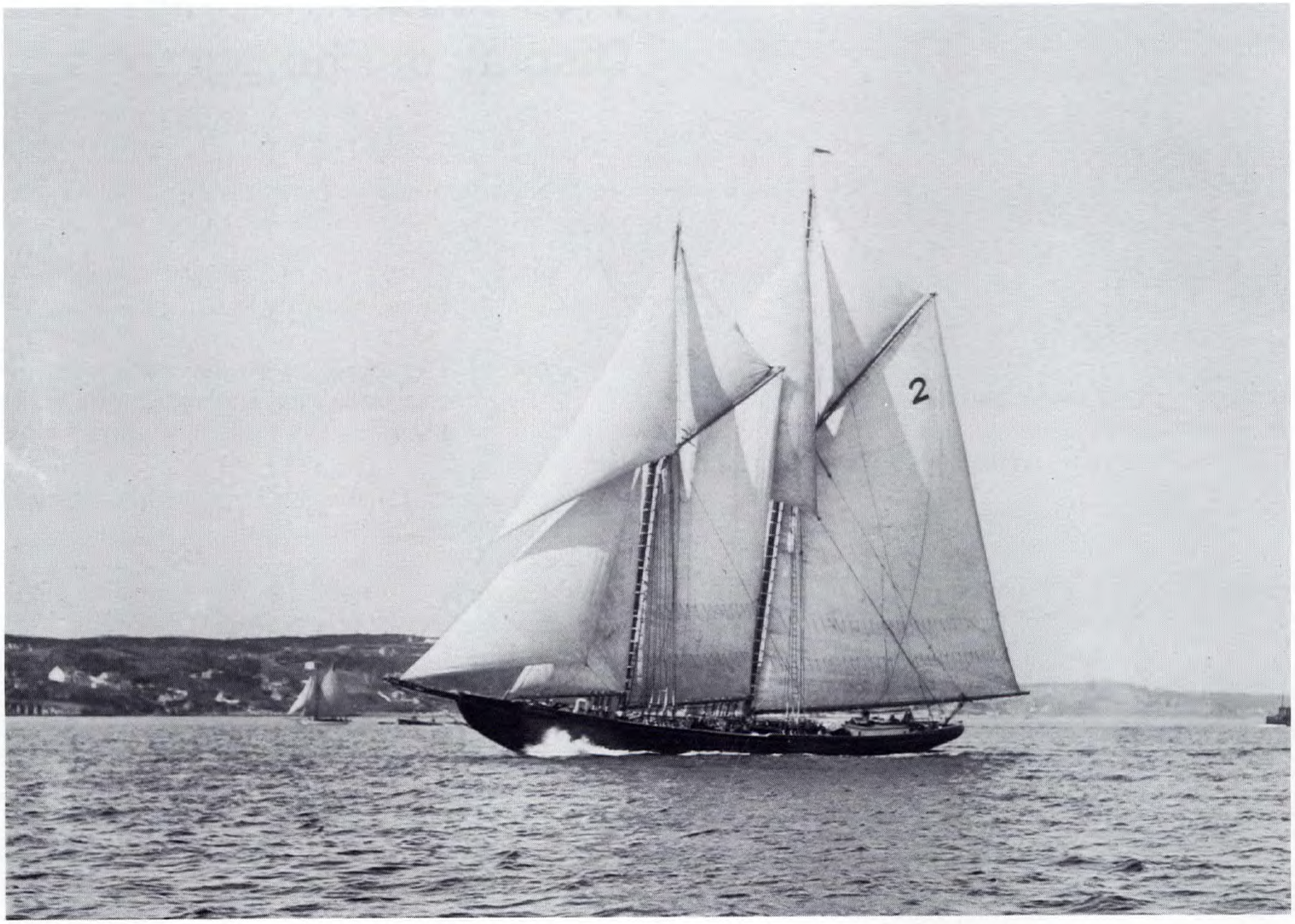
Hornsby, K.M. 1958. Reducers and Intensifiers with a Modern Negative Material. *British Journal of Photography* **105**: 42-46.

Levenson, G.I.P. 1952. Thick or Clear? *Functional Photography* **4**(3): 5-7.

Nietz, A.H., and K. Huse. 1918. The Sensitometry of Photographic Intensification. *Journal of the Franklin Institute* **185**(1105-1110): 389-408.

Perrin, Fred H., and J.H. Altman. 1952. Studies in the Resolving Power of Photographic Emulsions vs. the Effect of Reduction and Intensification. *Journal of the Optical Society of America* **42**(7): 462-467.

Scott, B.A. 1982. Image Enhancement Via Fluorescence. *British Journal of Photography* **129** (6376): 1123.



Bluenose under full sail. Halifax, Nova Scotia. 1921. Wallace R. MacAskill.
Contemporary print from copy negative of original print. National Archives of Canada/PA-030803.

9 Preservation, Storage, and Display of Photographs

9.1 Introduction

The photograph conservator will be called upon to advise curators about correct storage conditions, preservation, and display of photographic materials. These issues include the evaluation of filing enclosures, guidelines for the handling of photographs by researchers and staff members, and procedures to follow in the event of a flood, fire, or other disaster. The conservator can find guidance by consulting the large body of published standards and other articles concerning these issues, listed at the end of this chapter. Such standards have been established because of the volume of photographic materials produced annually, the degree to which photographs are used in government, business, education, historical research, and entertainment, and the massive numbers of photographs requiring protection in archives and museums. The necessity of maintaining certain protective measures for photographs can be stated here briefly and will be elaborated on elsewhere in this chapter.

The effects of *fluctuating relative humidity and temperature* (where both factors alternate between high and low levels) can be destructive to photographic materials. Since various components of photographic materials gain and release moisture at different rates, uneven shrinkage can occur. The conservator may be called upon to provide continuous monitoring of the storage environment with thermometers, hygrothermographs, and psychrometers. Ideally, complete records will be maintained and environmental fluctuations investigated.

The preservation of photographs begins with correct storage and environmental conditions. Some consideration must be given to procedures that repair and stabilize photographs and then possibly return them to poor-quality storage envelopes and an uncontrolled environment. Ideally, all archives, museums, and libraries should have environmental systems that meet the respective guidelines for the storage of photographic materials. Light sources should be provided with filters. Although threshold values for maximum limits of air pollution (for example, for hydrogen sulfide, sulfur dioxide, or nitrogen oxides) have not been determined by ANSI, other guidelines do exist for environmental conditions in archives and libraries (Wilson and Wessel, 1984; Mathey et al., 1983; Hendriks, 1989).

No matter how prepared and careful institutions and individuals are in protecting valuable collections, disasters can occur. Floods, fires, bursting pipes, and less visible threats from insect and bacterial attack on photographs can destroy large numbers of photographs stored in archives. The successful recovery of damaged materials depends on speed and a well-planned disaster recovery procedure that can be implemented quickly. Such planning requires the preparation of priority lists, which take into consideration the relative historical value and the relative stability of the objects in the collection, to determine the order in which items are to be treated.

Staff members who deal with photographs should be trained in the handling of these objects. Should the public be allowed access to original images, the photographs should be protected by mounts and enclosures, and suitably equipped inspection areas should be provided.

9.2 Storage Conditions

The establishment and maintenance of ideal storage conditions require that relative humidity, temperature, light, and air purity must all be controlled and monitored, although this is often difficult and can be costly. In addition, the quality of materials used in filing enclosures must be known.

Any discussion of storage conditions must deal with several areas of concern: environmental conditions (temperature, relative humidity, chemical purity of the air, and light levels); the use of cold storage for certain materials; guidelines for selecting filing enclosures; and the special problems involved with microfilm storage and filing enclosures. A brief introduction to some of the issues involved in these areas of concern will serve to introduce the more detailed discussions that follow.

Excessive heat, humidity, oxidizing gases, and light are rarely isolated phenomena, but factors that interact to initiate deterioration. Deterioration caused by environmental conditions is not sudden, as mechanical damage is, but occurs over a long period of time. Often, these forces are too slow to attract notice (Reilly, 1988). Acidic deterioration of a paper support by migrating acids from a poor quality mount board, for example, depends on the presence of moisture; the rate of reaction greatly increases as the temperature increases. Keeping relative humidity below 60% will discourage biological attack (fungus and mould) on gelatin materials. Henn and Olivares discussed the problem of keeping photographic negatives in areas of consistently high temperature and humidity and concluded that filing enclosures for negatives to be stored in the tropics should be treated with a fungicide (Henn and Olivares, 1960).

Heavily used collections require great care in the choice of filing enclosures and storage boxes. Material must be easily accessible and protected from mechanical damage, fingerprints, excessive pressure, dust, and each other. The choice of envelopes, sleeves, folders, and storage boxes should be made on the basis of the nature and condition of the photograph to be stored, the limitations of the storage space and, of course, the quality and workmanship of the materials used in the manufacture of these preservation supplies. Heavily used collections require sleeves, boxes, and mats that can withstand handling hundreds of times a year.

The location of storage areas within an institution and the placement of materials within a designated storage area are also important considerations. Basements tend to be damp and could contribute to the high humidity that exacerbates other problems. If there is flooding in an institution, the basement is the usual area where water will collect. As water moves towards the basement, debris and mud are collected and can contaminate photographs and filing materials. With an eye to possible flooding, storage boxes should never be placed directly on the floor, regardless of the building level on which they are stored. Bursting pipes or faulty sprinkler systems can cause considerable water damage. Wooden or metal skids, or baked enamel shelving, can minimize such damage by raising the boxes of photographs or negatives off the floor where water will accumulate. Because pipes do leak and burst, it is best to house photographs and negatives away from plumbing. If such an arrangement is unavoidable, sheets of polyethylene film can be spread across the top of the boxes at the top of the stacks area. Fire prevention equipment should be placed near collections and be readily accessible for extinguishing small fires. Fire-fighting systems such as carbon dioxide gas or water sprinklers with dry pipes ("pre-actioned" dry pipe system) for extinguishing fires the moment smoke or heat is detected are recommended where possible. A recent study explains: "A pre-actioned (dry pipe) system is charged with compressed air. For water to be delivered to a fire, two things must happen. First, electronic heat/smoke detectors must initiate the filling of the system with water. Secondly, a sprinkler head must be opened by heat, just as above. Therefore, if a head is damaged, air pressure in the system is lost but water is not immediately discharged. Occupants have time to close the valve supplying water to the system before it reaches the damaged head" (National Archives of Canada, 1989). Halon gas systems, which have excellent fire prevention properties, are no longer permitted in Canada.

9.2.1 Environmental Conditions

Careful and complete processing alone will not provide maximum stability for either black-and-white or color images (Eaton, 1987). The processed photographic materials must be placed in an environment that protects the original from excessive temperature, moisture, and any environmental or air-borne pollutants. The following sections will clarify acceptable storage and environmental limits for the storage of processed photographic materials. In some cases, the conservator will be called upon to suggest practical solutions and give innovative ideas to minimize the potential for deterioration. Where possible, we have included some ideas and solutions to problems that we have found useful.

9.2.1.1 Temperature

Temperature is often mentioned as a factor with a large influence upon the longevity of various objects of cultural heritage. This reputation is based on the observation that the rate of chemical reactions is temperature-dependent. Generally, the rate of a chemical reaction is increased with rising temperature; as a rule of thumb, reaction rates double with every increase of 10°C. This holds true only if we consider the presence of substances capable of reacting with each other to form new compounds. In the absence of reactive materials, degradation reactions cannot occur. For example, well-processed contemporary silver gelatin images on a stable support, i.e., fibre-base paper or polyester film, are essentially stable to moderate heat. The only chemical substances surrounding them, moisture and the oxygen and nitrogen in the air, do not ordinarily react with the components of such images. If, however, some reactive substances were present, such as residual processing chemicals in the image layer or hydrogen peroxide in the surroundings, they may react with the image silver to cause discoloration, a reaction that is accelerated at high temperature.

Turning now to color photographic images, the image-forming dyes, in contrast to image silver, are capable of reacting with water vapor and oxygen in the air resulting in the formation of dye degradation products. This may happen at room temperature and is described as dark fading. According to the observations noted earlier, dark fading reactions are accelerated at high temperature. This fact is made use of in accelerated aging experiments. Conversely, cold storage is the opposite of accelerated aging: chemical reaction rates are decreased dramatically with the result that the longevity of color photographs can be extended by several orders of magnitude. It is absolutely essential that recommended relative humidity levels be maintained when storing photographs at low temperatures.

Cold storage with controlled relative humidity has also been recommended for films on cellulose nitrate base. The rate of decomposition of this material increases faster with increasing temperature than that of other photographic records. However, since cellulose nitrate film is inherently unstable, the best provision for its long-term preservation is the preparation of duplicate negatives from the originals.

Temperature values, be they at a normal level or in cold storage, should not be allowed to fluctuate. Cycling temperature may lead to differential contraction and expansion of the components in a photograph, similar to that shown in Figures 9.1 and 9.2 in the section on relative humidity.

If the storage space is air-conditioned, fluctuating temperatures can indicate equipment malfunction. In such circumstances it is useful to understand how temperature influences original materials and how to control these fluctuations. In non-air-conditioned facilities, temperature fluctuations are unavoidable, but can be eased somewhat by the use of air circulation fans, by the placement of reflective film on windows to deflect the radiant energy from the sun, and by keeping the thermostat at appropriate levels during the winter months. Humidity levels must be monitored in conjunction with temperature levels, as a considerable increase in humidity can follow a drop in temperature of only a few degrees.

In summary, the level of temperature is not crucial to well-processed black-and-white photographs in the absence of chemically reactive materials as long as it is kept constant. The cycling of storage temperature of more than 4°C daily must be avoided. For color photographic images, cold storage at controlled relative humidity is the most cost-effective method for their long-term preservation.

Table 9.1: Recommended Temperature Conditions for the Storage of Safety Film (ANSI, 1985)

		Medium-Term Storage	Archival Storage
Sensitive Layer	Base Type	Maximum Temperature (°C)	Maximum Temperature (°C)
Microfilm:			
Silver gelatin	Cellulose ester	25	21
Silver gelatin	Polyester	25	21
Heat-processed silver	Polyester	25	21
General:			
Silver gelatin	Cellulose ester	25	21
Silver gelatin	Polyester	25	21
Color	Cellulose ester	10	2
Color	Polyester	10	2
Diazo	Cellulose ester	25	21
Diazo	Polyester	25	21
Vesicular	Polyester	25	21
Electrophotographic	Polyester	25	21
Photoplastic	Polyester	25	21

9.2.1.2 Relative Humidity

Relative humidity (RH) is defined as the ratio, expressed as a percentage, of the absolute humidity of sampled air to that of air saturated with water at the same temperature (Macleod, 1978). From the last section on temperature, we know that temperature alone does not determine how photographs gain or lose moisture, but that this is caused by a combination of relative humidity and temperature. This is important because the degree of moisture saturation of the air controls how much moisture will be taken up or released by water-absorbing materials.

$$\text{RH} = \frac{\text{absolute humidity of sampled air}}{\text{absolute humidity of saturated air (at the same temperature)}} \times 100$$

Relative humidity is the measure of how saturated with water a given amount of air is. It is temperature dependent in that the amount of moisture a set volume of air can hold increases as the temperature increases. Therefore, as the temperature of air is increased, the absolute humidity coincides with a smaller relative humidity. At a given RH, porous materials, such as wood, paper, leather, and textiles, will attain an equilibrium, specific for each material, at which they will have a constant moisture content. Similarly, photographic materials depend on a certain level of moisture in the air so that they can remain flexible and so that the binding medium, i.e., layers of gelatin or albumen, do not become desiccated, which may result in shrinking and cracking.

The presence of high relative humidity, as well as fluctuations in its level, can have an influence on the occurrence of chemical reactions or on the structure of a multi-layered record. Some chemical reactions do not take place readily in a dry atmosphere. For example, Pope has shown that residual thiosulfate left in microfilm does not react with image silver to any appreciable extent in an environment of 14% relative humidity. When the RH was raised to 88%, image silver deterioration was observed to occur after 14 days (Pope, 1963). Another example is the inability of acidic compounds in paper to cause hydrolysis of the chain of cellulose molecules in the absence of moisture. The action of an acid is, by definition, contingent upon the presence of water. Here again, a high relative humidity increases the rate of a hydrolysis reaction involving acidic compounds and the cellulose chain. One type of photograph known as a tintype has a base of an iron sheet. In a storage condition of high relative humidity, the iron may develop rust spots where surface cracks exist in the emulsion or lacquer layers.

Layers in a photograph consisting of unlike materials react differently with changes in the surrounding relative humidity level. This is demonstrated in Figures 9.1 and 9.2. The figures show a humidity chamber inside of which are placed an albumen print and a silver gelatin print. The relative humidity inside the chamber in Figure 9.1 is low, around 18%. Consequently, the two prints are curled up tightly, the albumen print

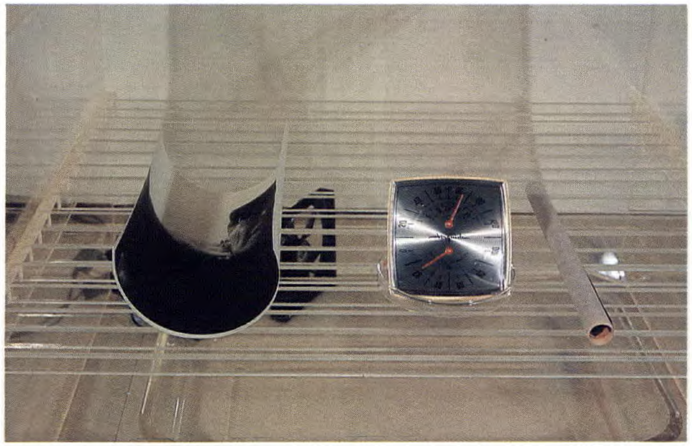


Fig. 9.1: The effect of a dry environment on a silver gelatin print, on the left, and a print on albumen paper. Both photographs are curled up at 18% RH.

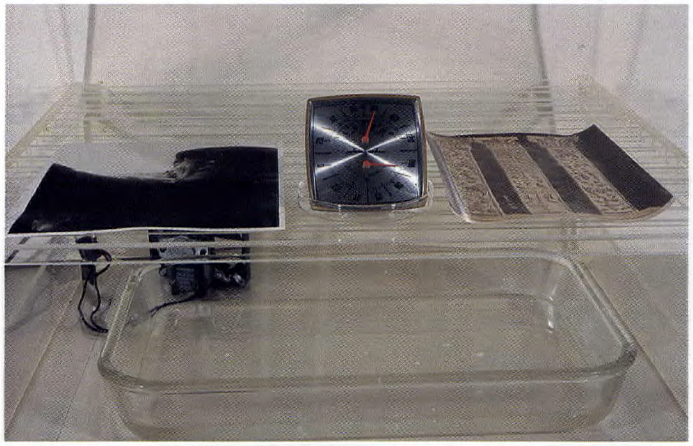


Fig. 9.2: The effect of a humid environment on the photographic prints shown in Figure 9.1. Both photographs have relaxed and are flattened by the surrounding 98% RH.

more so than the contemporary photograph. The binding medium in either photograph reacts to the dry environment at a faster rate than the paper support, i.e., it is quickly losing moisture and begins to contract. In so doing, it pulls the paper support along, with the result that the print rolls up. Figure 9.2 shows what happens if the relative humidity inside the chamber is raised to almost 100%: the binding medium absorbs water and expands, leading to a relaxed and flattened photographic print.

We have seen that relative humidity can trigger chemical reactions and that cycling of its level also may cause contraction and expansion of materials. A third effect is the growth of mould and mildew, which is encouraged in the presence of high relative humidity, i.e., a level exceeding 70%. That is true in particular for archival records containing gelatin, as in the case of gelatin-sized papers and photographic records where the image-forming substance is embedded in a gelatin layer. Examples are silver and dye gelatin images — the most common photographic records — as well as carbon prints and Woodburytypes.

Institutions that have centrally controlled environmental systems can generally monitor and maintain set climates. However, even in these circumstances, it is advisable that RH be monitored by an independent source. Several measuring and monitoring instruments are available for this purpose. We list the most commonly available devices below.

1. *Psychrometer*: This instrument consists of two thermometers, one to measure room temperature (dry bulb), and the other covered in cotton, which is kept moist with distilled water, and measures the cooling resulting from the evaporation of the water from the cotton (wet bulb). For example, if the RH were 100%, there would be no evaporation from the moist cotton and the two readings would be the same. As the RH drops, the moisture evaporates more quickly, and the difference in the readings between the wet and dry bulbs increases. The two values are then located on a table and the %RH determined (Macleod, 1978). Psychrometers require a controlled flow of air over the wet bulb during measurement to ensure consistent evaporation. The flow is generated by a built-in fan in some, or by spinning the thermometer by hand, as with sling psychrometers.

2. *Hair Hygrometer*: This device consists of bundles of hairs that lengthen as the humidity increases and shrink as the humidity decreases. These bundles are connected to a needle, which indicates the RH on a scale, or to a recording pen, which constantly records the RH on a chart. Many hair hygrometers also record temperature and are known as hygrothermographs or thermohygrographs. These types are most accurate within the 30% to 80% RH range, but generally are less accurate than psychrometers (Macleod, 1978). Recording hygrometers are used extensively for constant monitoring of collections. This type of recorder needs frequent calibration by checking the accuracy against a psychrometer or a dew-point hygrometer.

3. *Dew-Point Hygrometer*: This instrument provides a very high degree of accuracy and consists of various mechanical devices for cooling a sample of air until condensation occurs. The point or temperature at which condensation occurs is known as the dew-point. By consulting tables or charts, the RH is determined from the dew-point temperature for the particular environment (Macleod, 1978). Determining the RH with this device requires considerable skill. The mechanism is designed for single readings, rather than continuous monitoring and recording of RH values. For these reasons, they are rarely used in archives and museums.

Portable dehumidifiers may be required in summer months, and portable humidifiers may be used in winter. Fans should be used to circulate the air. Windows should be kept closed in the summer to make fluctuations more gradual as the outside temperature increases. The following tables summarize recommended storage conditions with regard to RH levels.

Table 9.2: Recommended Relative Humidity Ranges for Storage of Processed Safety Photographic Film (ANSI, 1985)

		Medium-Term Storage	Archival Storage
Sensitive Layer	Base Type	Relative Humidity Range (%)	Relative Humidity Range (%)
Microfilm:			
Silver gelatin	Cellulose ester	15-60	15-40
Silver gelatin	Polyester	30-60	30-40
Heat-processed silver	Polyester	15-60	15-50
General:			
Silver gelatin	Cellulose ester	15-60	15-50
Silver gelatin	Polyester	30-60	30-50
Color	Cellulose ester	15-30	15-30
Color	Polyester	25-30	25-30
Diazo	Cellulose ester	15-50	15-30
Diazo	Polyester	15-60	15-30
Vesicular	Polyester	15-60	15-50
Electrophotographic	Polyester	15-60	15-50
Photoplastic	Polyester	15-60	15-50

Micro-Environments

Oil paintings conservators and restorers have long been interested in providing micro-environments for fragile panel and canvas paintings (Constable, 1934; MacIntyre, 1934). Recently, cases have been designed and built containing silica gel panels, pre-conditioned to the desired relative humidity, which block the migration of moisture and atmospheric pollutants into the frame (Sack, 1978; Michalski, 1987). The case, constructed of aluminum and glass with a high quality foam or a silicone seal, eliminates the concern of deleterious ambient environmental conditions. Although constructing this type of frame is an expensive proposition, it should be considered for valuable objects, as nothing will protect them to the same extent.

9.2.1.3 Chemical Purity of Air

The volume of air-borne oxidizing agents (chemicals) and particulate matter, which is often present in the air from a variety of sources, is an area of special concern for photographic collections, particularly for those in industrial regions. There are several sources of this invisible threat to photographic materials.

Air Pollution: The burning of fossil fuels, particularly in industrial regions where by-products will be more concentrated in the atmosphere, results in the presence of sulfur dioxide and nitrogen oxides in the air.

Paint Fumes and Vapors: Photographic materials should not be placed in rooms freshly painted with oil-base paints, which can produce concentrations of peroxides high enough to attack image silver (Feldman, 1981).

Wooden Shelving, Boxes, and Drawers: Bleached or resinous wood that has not been treated with an acrylic resin can release peroxides, which are strong oxidizing agents.

Unstable Materials Kept in Proximity to Photographs: Deteriorating cellulose nitrate film gives off nitrogen oxides, which convert to nitric acid in the presence of moisture. In sufficient quantity, these fumes will attack other sensitive materials as well as accelerate the deterioration of the nitrate base of the film itself (Carroll and Calhoun, 1955).

Air-borne Particulate Matter: Dust and metallic particles in the air can cause mechanical damage (abrasion) to the surface of photographs, if trapped in enclosures or left to settle on unprotected photograph surfaces. Large build-ups of dust are hygroscopic and can initiate bacterial or mould growth. Metal particles may stain paper supports, in the presence of high humidity.

Metallic image silver, with its fine filamentary structure and small grain size, is particularly susceptible to damage resulting from oxidizing gases. Sulfur compounds, such as sulfur dioxide, readily attack image silver, resulting in the conversion of metallic silver to silver sulfide, which discolors and often causes images to fade. The rate of this type of deterioration is accelerated greatly in the presence of elevated temperature and high relative humidity. It is difficult to eliminate all traces of oxidizing gases, particularly if the space is heavily used by the public. Added protection may be provided to certain objects by keeping them isolated in areas where little or no traffic occurs. Institutions with no controls over air purity available to them can ensure that collections are protected by providing high-quality filing enclosures and boxes with lids to keep out dust and to help filter out some of the oxidizing gases. Windows should be kept closed. Intake fans should be enclosed with filters for particulate matter. Ozone-producing electrostatic air purifiers and precipitators should not be used (Lafontaine, 1981).

Several pieces of equipment are available to determine the level of certain gases in the air, such as trace gas analysers for hydrocarbons; however, most analysers are too expensive to be found in small collections and museums. The actual determination of the presence of oxidizing gases requires sophisticated analytical techniques unavailable to most facilities. This analysis can be carried out by contract with businesses that provide such services.

Recommendations: There are no established safe or acceptable levels for oxidizing gases. Collections without proper air filtration systems must remove obvious sources of such contaminants. Air should be filtered to remove particulate matter. The level of dust removal should be 95% of particles 1 μm in diameter or larger, and 50% of particles between 0.5 and 1 μm in diameter (Lafontaine, 1981).

Table 9.3 summarizes recommended storage conditions with regard to gaseous and particulate pollutants as developed in a study at the U.S. National Bureau of Standards by Mathey and co-workers (Mathey et al., 1983).

Table 9.3: Recommended Storage Conditions with Regard to Gaseous and Particulate Pollutants

Concentration of Contaminant, $\mu g/m^3$

Contaminant	Category 1	Category 2	Category 3
SO_2	≤ 1	≤ 1	≤ 1
NO_x	≤ 5	≤ 5	≤ 1
O_3	≤ 25	≤ 25	≤ 25
CO_2	≤ 4.5	≤ 4.5	≤ 4.5
HCl Acetic Acid HCHO	Use Best Control Technology		
Fine particles (total suspended particulate)	≤ 75	≤ 75	≤ 75
Metallic fumes	Use Best Control Technology		

9.2.1.4 Light

Light is defined as the visible part of the electromagnetic wave spectrum that stretches from short-wavelength gamma rays to radio waves that may be one kilometer or more long. Visible light and the adjacent ultra-violet radiation (with a shorter wavelength than visible light) have long been considered as a potent threat to the longevity of the holdings in museums and galleries. This may be true for objects that are on permanent display in the type of institution noted above. It is not difficult to find examples of objects that have been damaged, in one way or another, by light. Those objects, in many instances, have been exposed to light for many years and so have lost color saturation, as can be observed in textiles or watercolors. Little is learnt from such observations; instead it is urgent, as Thomson (1986) suggests, to establish fading rates for light-sensitive museum objects. In most photograph collections, images are stored away from light: they are kept in filing enclosures that are stored in boxes. Many photographs have survived well because they were kept in albums. When photographs are accessioned, catalogued or examined by people, exposure to light cannot be considered a serious hazard because of the short exposure times of a few hours or days. During or after such work, photographs should not be left lying around unattended, and they should never be exposed to direct sunlight.

The decision to display photographs must be considered carefully. Some thoughts on the exhibition of photographs with pertinent recommendations are found in Section 9.8.

9.2.2 Cold Storage

There is a marked difference between the stability of black-and-white materials and those in color. Early instructions by the manufacturers stressed the importance of keeping photographic materials cool, dry, and dark. So it seems practical that the storage of photographic materials, especially color materials, would benefit from the use of cold-storage facilities. As in the case for motion picture film, cold storage for color still photographs is highly recommended. Storage at controlled low temperatures slows down the dye change in color materials (Widmayer, 1961). In 1979 R.J. Tuite discussed the temperature dependence of dye fading with reference to the long-term stability of color images. Table 9.4 below is Tuite's estimation of the effect of temperature on image stability.

Table 9.4: Effect of Temperature on Stability of Image Dyes (Tuite, 1979)

Storage Temperature, °C	Predicted Time (*t*) at 40% RH for 0.1 density loss from D = 1.0
30	1/2 *t*
24	*t*
13	4 *t*
4	16 *t*
-18	340 *t*

Humidity control is as important as temperature control in cold storage. The lower the temperature, the less moisture the air can hold before moisture condenses on surfaces. It is difficult to control the humidity at freezing and below-freezing temperatures, because the air becomes saturated with relatively small amounts of moisture. Also, when an object is removed from a freezer, moisture from the surrounding room-temperature air quickly condenses onto the surface of the frozen object as it begins to thaw. Thus, if humidity levels inside a freezer go above certain concentrations (which is a consequence of opening and closing the unit), ice crystals may form on the surfaces of objects stored within. For this reason, frequently used collections cannot be placed in cold storage. For small, seldom-used collections, frost-free refrigerators may be suitable for long-term storage, provided that procedures (leave refrigerator door closed in the event of a power failure up to 48 hours, or open door if power is off for more than 48 hours) are instituted for extended periods of power failure (Wilhelm, 1978). Modern frost-free refrigerators can maintain temperatures of ± 1.5°C and provide year-round relative humidity levels of 25-30%, in spite of fluctuations in the ambient temperature and relative humidity. There are certain precautions that must be taken.

1. Test the relative humidity and temperature inside the refrigerator before use.

2. Use only the refrigerator, not the freezer, for unprotected storage of photographs.

3. Photographs should be placed inside acid-free cardboard boxes to buffer them against fluctuations when the refrigerator door is opened.

4. When an item is removed from the refrigerator, place the boxed material in a plastic bag, seal it, and let it sit for at least two hours while it warms to room temperature, so that condensation does not form.

5. Avoid opening the refrigerator door more than is necessary.

Temperatures of well below freezing can provide even greater protection for permanently stored color images and can thus extend their life indefinitely. When stored at temperatures around -20°C, they must be pre-conditioned to a low humidity and then placed into air-tight envelopes or vapor-tight containers (Wilhelm, 1978). Cold storage in temperatures below freezing has been recommended for nitrate-base negatives. Small quantities of valuable nitrate films can be protected by first placing them in proper vapor-proof foil cold storage envelopes, squeezing out the air, and heat-sealing the ends. Proper sealing of the envelopes is essential to prevent moisture build-up on the inside film surfaces. The envelopes are then placed in boxes for further protection and deposited in the freezing unit (Haynes, 1981). In 1985, Eastman Kodak performed experiments that addressed the question of cycling conditions with respect to motion picture film, one-color paper, and the physical stability of seven films. "In another experiment, samples of seven films and one color paper were pre-equilibrated at 24°C and 45% RH, heat-sealed in foil envelopes, and stored in a freezer at -15 to -12°C for 6 months. During each working day, the samples were removed from the freezer for 4 hours. This was sufficient time for the samples to be at room temperature for several hours during each cycle. They were then replaced in the freezer. Wedge brittleness, mushiness and wet and dry cycle adhesion tests similar to those in ANSI PH1.41, as well as image stability tests were performed after 6 months' cycling. No adverse effects were seen as a result of the freeze/thaw cycling" (Kopperl and Bard, 1985).

9.2.3 Filing Enclosures

Filing enclosures (sleeves, envelopes, and folders) and storage boxes must provide a safe environment and be stable chemically for photographic materials. For that reason, the chemical stability of filing enclosures and how these materials interact with the environment should not be forgotten by the photograph conservator (Reilly, 1986). The kind of filing enclosures selected to house a particular group of photographs depends upon several factors:

a. *The kind of photographic image (e.g., albumen print, glass plate negative, silver gelatin photograph).*

According to recent studies regarding the stability of albumen photographs, *alkaline* buffered filing enclosures accelerate the deterioration of these 19th-century images (Reilly, 1982). Albumen prints by nature have a slightly acidic pH. Placing them in alkaline conditions can be destructive. Kodak dye transfer prints are extremely acidic (pH 4.0); these images can be severely altered by alkaline conditions. Photographic gelatin is also acidic by nature (pH 4.7-5.5) and can be adversely affected by alkaline enclosures. Although very little laboratory research has been conducted regarding silver gelatin prints and buffered enclosures, the nature of the photographic material itself leads us to conclude that *neutral* pH enclosures are certainly best for collections that contain various historical photographic processes.

b. *The physical condition of the material (e.g., unmounted albumen print, rolled panoramic photograph, encased ambrotype).*

Some fragile glass negatives with blistering emulsions, and broken negatives, can be stored in protective sandwiches of glass. Relaxed (previously rolled) panoramic photographs may need constant support to keep them flat. This may be provided by a mount board support, or by encapsulating the image in heavy Mylar. Unmounted photographs may need Mylar sleeves or paper jackets to protect them from mechanical damage. Although mounted images may be stored in vertical filing cabinets, unmounted images have a tendency to curl unless stored flat or provided with additional support. Some rare photographs may warrant careful mounting and matting, with a protective Mylar window to prevent problems associated with handling. These are only a few of the variety of preservation housing requirements found in typical collections.

c. *The size of the individual item.*

Oversized items may require specialized storage procedures and mounting requirements. It is perfectly acceptable to lay large matted, encapsulated, or foldered photographs atop one another in a shallow map case drawer, but it is not desirable to build a tall stack of such items on a shelf, where the temptation will arise to simply pull a bottom-layer item out by force, rather than unstacking the entire pile. In the case of glass negatives, even a small horizontally stored pile puts considerable pressure on the bottom negative. When glass is stored vertically, it should be stored on its longest edge, in the case of very large negatives, and should be supported in slotted baked enamel or aluminum boxes. Prints that are very small should be housed in sleeves or envelopes that prevent them from sliding underneath the edges of larger images. Items should never be placed inside a sleeve or envelope that fits too tightly, as this can cause the image to curl or buckle.

d. *The size of the collection needing preservation housing.*

The size of the collection may prescribe how the collection is stored. A news agency archive of 80,000 prints may require a large number of Mylar sleeves, paper jackets, file folders, and/or manuscript boxes. With the expense of such filing enclosure materials, the photograph conservator must be prepared to suggest acceptable, if less than ideal, solutions. A small collection may allow for custom-made or hand-constructed enclosures, but large collections require some kind of standardized housing method.

e. *The size and availability of storage space.*

Institutions may have plenty of filing cabinets, but no shelf space, or may have lots of narrowly spaced shelves, but no space for tall manuscript boxes. The photograph conservator who proposes preservation housings may have to have innovative suggestions for methods and housing techniques; otherwise, the suggestions may be ignored, perhaps to the detriment of the collection. For example, four or five Mylar encapsulated panoramas may fit in the space required to store one such panorama supported by an eight-ply mount board. An acceptable compromise might be to use one such support board in a folder housing several panoramas stored horizontally.

f. *The frequency of handling of the images by researchers.*

Collections that are heavily used by the public must be protected. This is especially true for vintage images, but even modern copy photographs, which are expensive to obtain, must be able to withstand many decades of handling. Clear triacetate or polyester sleeves, although more expensive than paper envelopes, allow the material to be viewed without removing the sleeves; such removal and reinsertion may subject the photograph to abrasion over a period of time. Furthermore, researchers can photocopy appropriate images through these transparent sleeves. In the case of large collections, where dozens of images are stored horizontally or vertically in boxes, a clear and logical arrangement and labelling of the collection can reduce the amount of handling of individual pictures. It can also reduce the number of times boxes are retrieved from and returned to storage. The use of detailed finding aids with collections, although not a preservation issue per se, can eliminate the need for researchers to sift through dozens of boxes or drawers of pictures. Rare and valuable images should be given special housing and should be replaced with surrogate copy photographs, which will meet the reference needs of all but the occasional researcher.

g. *The relative value of the photograph (e.g., documentary photograph, fine art photograph, rare image, or ordinary family snapshot).*

The distinction between fine art and documentary or historical photographs can be a difficult one to maintain in archives where some documentary images have attained a value that equals or exceeds photographs that were intended as art. However, in practice, one must make such distinctions to determine how much time, money, and storage space will be spent to house a particular picture. Fine art photographs are usually mounted and matted according to traditional prints and drawings conservation techniques. They are then usually stored inside horizontal archival storage boxes. Historical collections, numbering not in the hundreds of images, but in the tens and hundreds of thousands, are usually stored in filing cabinets, or by the dozens or hundreds in boxes. However, despite their relatively low market value, documentary collections sometimes contain images that are of inestimable historical value. Careful thought should be given to the storage of documentary collections. Items should be adequately supported and sleeved in vertical manuscript boxes. Photographs awaiting processing should be protected from dust and light by placing them inside filing cabinets or closed boxes.

h. *The preservation supply budget limitations of the custodial institution.*

A Mylar sleeve, acid-free file folder, or paper envelope for one photograph can be expensive, even when purchased in enormous quantities. Mounting and matting add more costs. Archival boxes can be very expensive, depending on the type. The conservator must work closely with the curator or collection custodian to find preservation solutions that can actually be implemented within the budget constraints of the institution. At the very least, groups of loose photographs might be stored horizontally in archival boxes, for protection against deterioration. The conservator should be prepared to search preservation supply catalogues for the least expensive, acceptable quality products, and should make these suggestions to the custodial institution.

Recommendations: The American National Standards Institute has published specifications for filing enclosures and distinguishes between folder, sleeves, and envelopes. Their shape and the location of seams with adhesives is spelled out, with recommendations as to the type of materials to be used (ANSI, 1988a; Hendriks, 1984). In general, for plastic sleeves and folders, three materials are acceptable: uncoated polyester (Mylar), cellulose triacetate, and polyethylene. The issue of appropriate materials for use in contact with photographic images continues to be an area of active and continuing research (Williams, 1985).

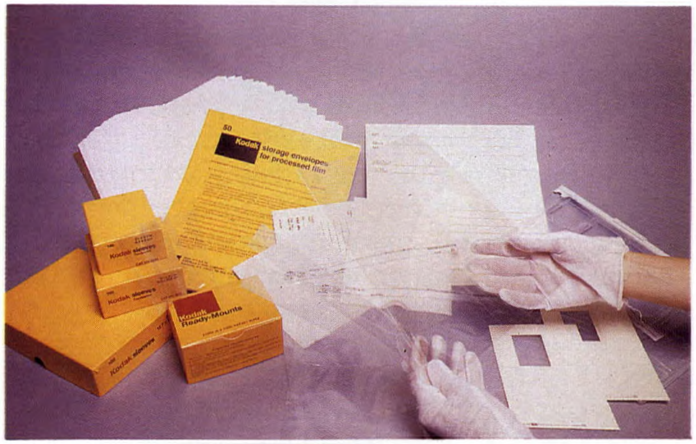


Fig. 9.3: Examples of various forms of filing enclosures.

9.2.4 Microfilm Storage and Enclosures

Contemporary microfilms are made in black-and-white (by silver halide and non-silver processes) and in color. Specific generic examples include:

- black-and-white silver gelatin film
- thermally processed silver (TPS) film
- diazo film
- vesicular film
- color microfilm by silver dye bleach processes
- color microfilm by chromogenic processes

The first four of these are in monochrome.

ANSI specifies that archival record films must have a gelatin silver halide emulsion on safety film and the image must be processed to standards for silver gelatin black-and-white photographic films, in compliance with specified processing procedures. Diazo and vesicular films are images formed by dyes and therefore are not approved as archival record film, even though they show good image stability. They are recommended, however, for "long-term records," which are defined as records providing usable images for a minimum of 100 years when stored under archival conditions (Eastman Kodak, 1983).

ANSI has discussed the stability of some non-silver microfilms in an ANSI Standard (ANSI, 1988b) IT9.5-1988, *Ammonia-Processed Diazo Films — Specifications for Stability*. This document outlines specifications for their manufacture, processing, and storage requirements, in addition to an appendix that covers microfilm image quality.

Silver gelatin microfilms make up the majority of microfilm materials. They should be processed and stored according to specifications for all other silver gelatin materials. Diazo and vesicular films are similar in their requirements for storage, although they are somewhat more sensitive to heat (Eastman Kodak, 1983).

The major preservation concern regarding silver gelatin microfilms during the last 20 years has been the formation of microscopically small spots on the film, known as redox blemishes. After considerable investigation, it was observed that the spots had formed primarily on leaders and edges, with gradual movement into image areas. It was determined that these spots occurred where image silver had been oxidized, dissipated, and then replaced by colloidal silver. Investigations into the source of oxidizing agents revealed that those stored in metal cans were almost entirely free of blemishes. Therefore, the likely source of peroxides was the cardboard boxes in which rolls were stored. Microfilm reels made from cardboard or lignin-containing woodpulp fibres were also sources of peroxides. The action on the silver grains was greatly accelerated by elevated storage temperatures and relative humidity. Poor processing of films was also found to be a major contributor to the formation of redox blemishes (McCamy and Pope, 1970).

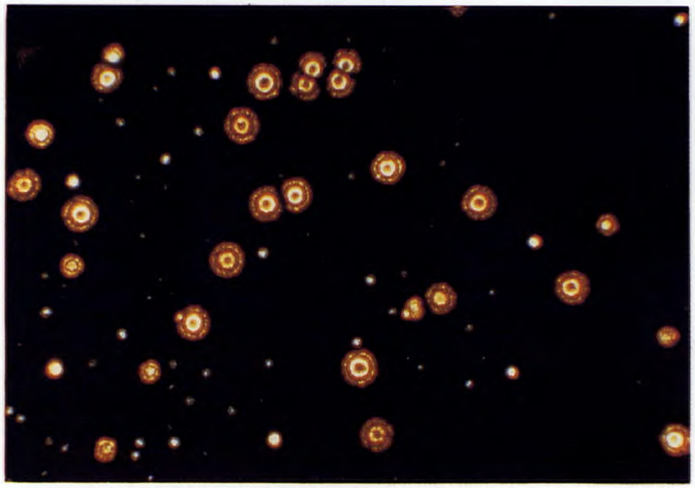


Fig. 9.4: Shows redox blemishes on processed microfilm at a magnification of 50 times.

Recommendations for the control of redox blemishes:

a. Storage conditions as outlined in ANSI Standard PH1.43-1985.

b. Processing to limit the residual thiosulfate concentration to a maximum of 1 μgram/cm^2.

c. Use of inert materials for storage containers, such as metal (non-corroding) and inert plastics.

d. The use of low concentrations of potassium iodide in the fixing bath (0.2 gram/liter) has also been found to protect against blemishes (Henn et al., 1965).

Details on the preservation and storage of microfilm have been described by Hendriks (1987).

9.3 Handling of Photographs

Researchers who wish to study photographs should understand that frequent handling of photographs causes deterioration and the rules governing the handling of photographs is for the protection of the material. Only pencils should be used near photographs. Researchers should not take notes on top of photographs, as a sharp pencil will make an impression in the surface of photographs. Photographs should not be piled on the floor or chairs as researchers sift through filing cabinets or boxes of images. Researchers should be careful to avoid the abrasion that occurs when quickly shuffling through large groups of unprotected pictures. Photographs, particularly those that are unmounted, should be lifted by two corners at once. Photographic mounts, some containing valuable inscriptions, may be brittle and crumble easily. They should be handled gently. Photographs should not be crammed into boxes, or removed from boxes that are only partly opened. Metal clips or other types of fasteners should not be used on photographs. Photographs that have been placed in polyester sleeves should not be removed unless it is necessary. Food and beverages should not be brought into the vicinity where photographic materials are used or stored. Spills damage photographs directly; crumbs attract insects and rodents, which may threaten the collections.

Researchers and staff members should wear white cotton or nylon gloves when handling photographs. As innocuous as they may seem, fingerprints can result in irreparable damage to photographs. The grease from fresh prints can be removed using Kodak Film Cleaner or anhydrous ethyl alcohol. After a period of time, fingerprints have been observed to etch the surface of the gelatin (Hendriks, 1989). Fingerprints have also resulted in the sulfiding of the image silver. Figure 9.5 shows silver mirroring on the silver gelatin glass plate caused by a fingerprint. Moisture from hands can trap dust and dirt, which is hygroscopic and may contribute to the growth of mould and bacteria on the surface of the print or negative. The edges and corners of photographs and mounts can

Fig. 9.5: Silver mirroring on a silver gelatin glass plate negative caused by a fingerprint.

quickly become disfigured by dirty or greasy finger and handprints. Gloves are inexpensive when purchased in large quantities and can be replaced when dirty, or laundered and re-used. Discard gloves when they develop holes, which can catch on flaking emulsions. Some conservators prefer nylon gloves, because they are smoother. Others find that cotton gloves provide a better grip when handling smooth materials such as glass plate negatives and ambrotypes.

Photographs and negatives should be supported while being transported from one area to another. Special closed boxes can be constructed to protect glass negatives and case photographs that are retrieved from storage. Any storage boxes that contain glass items, such as lantern slides, case photographs, or negatives, should be clearly marked on the outside, to caution the staff and researchers. Carts should be used to retrieve materials from storage and to move boxes of photographs through doorways. To carry boxes of photographs or negatives up and down stairways is unnecessarily risky when elevators are available. In processing areas, folders containing photographs should be marked to warn others against piling boxes and other heavy materials on top. Oversized material should be supported across the bottom when carried. If necessary, a second person should help to carry a very large item.

Photographic albums should be handled with care by staff members and researchers. Specially designed cradles or supports can be fashioned to reduce the angle to which the book is opened. Both hands should be used to turn pages, and gloves must be worn. Pages that are stuck together should not be forced apart. If it is necessary to remove *cartes-de-visite* and cabinet cards from their apertures in 19th-century family albums, a pair of long, flat tweezers can sometimes be used without tearing the surrounding mat. Alternatively, two pictures (placed back-to-back on the recto and verso of an album page and sharing the same aperture) can be pinched together in the center and slid out the bottom or top page opening together. Care should be taken to prevent rotted leather particles from flaking off onto photographs inside or near albums that are badly deteriorated.

If it is necessary to write information on a photographic print, it should be written on the back of the print with an HB pencil. Preferably, the location of the written information should be in a non-image area or in an area of minimum detail. Care must be taken to avoid pressure so as to prevent an impression in the surface of the photograph. We recommend this as a result of a study of marking devices in our laboratory. The study involved the investigation of porous tip, felt tip, and permanent markers, as well as grease pencils, stamping inks, ink pens, and pencils. We concluded that an HB pencil was most suitable for writing on photographic prints in the manner described above. Writing done with an HB pencil will not smudge or bleed when wet or transfer to another print when in contact with it; the graphite is chemically inert when used alone and its marks are easily removed with a soft eraser. Markers for photographic films were not part of the study.

The appearance and integrity of the surface of a photographic print are principal factors in its aesthetic value. Surface properties are described in such terms as gloss, mat, lustre, and texture. They are, in combination with the image tone, inherent characteristics of a photographic print. Disturbing or destroying these delicate surface qualities changes the aesthetic value of the print.

Thoughtful handling practices can play a significant role in increasing the longevity of photographic materials and should therefore become a normal part of life when dealing with photographs in collections.

9.4 Emergency and Disaster Preparedness Procedures

Even with the most recent advancements in the design of safe and sound storage areas, accidents and natural disasters can occur. Floods, fires, hurricanes, and tornadoes can threaten historical documents. Water damage is the most common emergency, from floods, storms, leaking pipes, faulty sprinkler systems, and firefighter's hoses. Most archival materials will be severely damaged or destroyed by the action of water, unless a prompt, well-organized recovery program is in place to minimize the loss of photographs. Hendriks and Lesser (1983) tested historical and contemporary film samples to determine their stability in water over extended periods of time and to determine the effects of various drying techniques on these materials. The recommendations that follow are based on those findings and those of other workers (Eastman Kodak, 1985a).

9.4.1 Procedures for Black-and-White and Color Negatives and Print Materials

As soon as time, facilities, and personnel become available, treat water-soaked materials in the following manner, according to the priorities laid out below.

Recovery Treatments

A. *If photographs can be treated immediately, air dry them.*

1. Keep immersion time to a minimum.
2. Keep the photographs wet until they have been separated from filing enclosures and each other. Never allow them to dry while in contact with anything else, as they will stick together permanently.
3. Gently rinse them in clean water if they are covered with surface dirt.
4. Place them on clean photographic blotting paper or nylon screens, emulsion side up. If the emulsion layer is quite hard, prints on paper can be placed face down to minimize curling.
5. Because some materials are more stable than others, treat the least stable items first, according to the given chart. The solubility of photographic materials in water depends on the type of material, how it was processed, and the temperature of the water. Some photographs survive less than 24 hours; some may last up to four days; others will be destroyed almost immediately.

Stability and Maximum Immersion Time	Types of Photographic Materials
will not survive immersion	Starch prints — early color processes: Autochromes Dufay Color Paget Finlay Agfa color
less than 24 hours	Wet collodion glass plate negatives (including ambrotypes and tintypes) Silver gelatin glass plate negatives
maximum of 48 hours	Color materials (contemporary) Silver gelatin prints Silver gelatin negatives Salted paper prints
3 to 4 days	Collodio-chloride prints Albumen prints

B. *If items cannot be treated immediately, freeze-thaw and air dry them.*

1. Gently rinse the materials in clean cold water to remove any surface dirt.
2. Place the material into plastic bags, seal the bags, and place them in a freezer. Items can remain frozen almost indefinitely.

3. When ready to treat the materials, allow them to thaw. It may be necessary to re-immerse the material in cold water to ensure that it does not dry before it is separated. Otherwise, it will stick permanently.
4. Place separated materials on clean blotter paper or nylon screens, emulsion side up.
5. If the emulsion layer is quite hard, prints on paper can be placed face down to minimize curling.

C. *If time, materials, and space are not available for air drying, freeze-dry.*

1. Never freeze-dry wet collodion glass plate negatives.
2. Gently rinse photographs in clean water to remove surface dirt.
3. Place photographs in plastic bags, tightly seal, and freeze.
4. When ready to treat, remove the photographs from the plastic bags and follow the same procedures as used when freeze-drying other archival materials.
5. Freeze-drying can result in some damage to the photograph, such as dimensional changes, density loss, and changes in surface gloss.

D. *Never freeze-thaw-vacuum dry.*

Everything will stick permanently into a solid block!

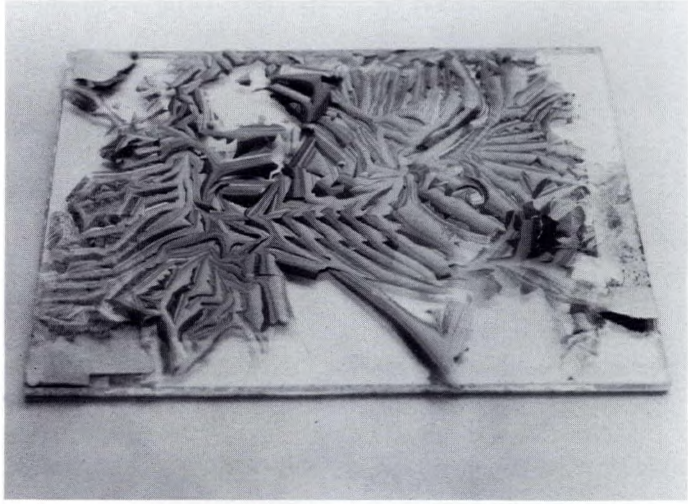


Fig. 9.6: A freeze-dried wet collodion glass plate negative, showing complete destruction of the image layer.

9.4.2 Procedures for Black-and-White and Color Microfilms and Motion Picture Films

The same general procedures apply for these materials as for still pictures. However, because few archives have the space or equipment to wash and dry reels of film stock, the following procedures should be followed.

1. Keep the film immersed in cold water.
2. Rush the film to a film processing facility that is prepared to wash and dry the soaked film in a commercial processing machine.
3. If this requires a long trip, add ice to the cold water to keep the temperature low.

Table 9.5: Disaster Preparedness: Salvage of Water-Soaked Photographic Collections

Material	Priority	Precautions	Procedures	Drying Method
Photographic Materials				
Materials Using a Collodion Binder				
Ambrotypes Tintypes Collodion Wet Plate Negatives	***Prevent*** this type of material from being immersed in water.	Removal from case and disassembly may be necessary.	The use of water-tight boxes or covering materials should be considered.	Air dry (without freezing).
Collodio-chloride Prints	Maximum immersion time 36 to 48 hours.	Same as gelatin prints.	Same as gelatin prints.	Refer to gelatin emulsions.
Materials Using an Albumen Binder				
Albumen Negatives Albumen Positives	Dry within 36 to 48 hours.	If photographs are fragile, place in a sealed plastic bag to minimize drying. Then place bag in cold water.	Keep the immersion time to a minimum, and maintain wetness until they can be separated from the filing enclosure.	Air dry.
Materials Using a Gelatin Emulsion				
Gelatin Dry Plate Negatives	Maximum immersion time 24 hours.			
Roll Films Sheet Films Cellulose Nitrate Films Cellulose Diacetate Films Cellulose Triacetate Films Polyethylene Terephthalate Developing-out Papers Printing-out Papers Resin-Coated Papers	Keep immersion time to a minimum (48 hours) and air dry immediately or freeze wrapped in a garbage bag.	Do not allow the emulsion to come in contact with other materials unless being frozen.	If time and personnel are available, separate and air dry.	1. Air dry (without freezing); 2. Freeze-thaw-air dry; 3. Freeze-dry in vacuum chamber.
Instant B/W Photographs				

Table 9.5: Disaster Preparedness: Salvage of Water-Soaked Photographic Collections (continued)

Material	Priority	Precautions	Procedures	Drying Method
Monochrome Non-Silver Materials				
Cyanotypes Carbon Prints Woodburytypes Collotypes	Dry within 48 hours.	Do not blot and handle the support side only.	Separate and air dry or freeze unless time and personnel are not available.	Air dry.
Additive Color Processes				
Color Screen Plates	***Prevent*** from ever being in contact with or soaked in water (zero immersion time).	Do not blot or handle the image side.	Use water resistant housing materials and/or watertight materials.	If they survive, air dry.
Subtractive Color Processes				
Kodachrome Films Ektachrome Transparencies Color Negative Materials Chromogenic Color Print Materials	Keep images in ***cold*** water. Immersion must be less than 48 hours.	Do not allow the emulsion to come in contact with other materials unless frozen.	If they cannot be immediately treated, place in a standard garbage bag and freeze.	If wet—air dry. If frozen—thaw-air dry.
Silver Dye Bleach Materials				
Dye Transfer	As above.	As above.	As above.	As above.
Dye Diffusion Transfer				

9.5 Experiment 1: Use of the Hygrothermograph and Sling Psychrometer

Purpose

To demonstrate the use and compare the accuracy of a sling psychrometer, a Bendix Psychron psychrometer, and a recording hygrothermograph.

Introduction

Relative humidity plays a principal role in determining the effect that the storage environment will have on photographic materials placed therein. Moisture is necessary for many chemical and biochemical reactions to proceed. At the same time, a certain amount of moisture in the air is required to keep photographic emulsions and paper supports flexible. The goal is to strike the right balance between too much and too little ambient air moisture content. Consequently, the use of accurate measuring instruments is a necessity. We will use three such instruments in this experiment.

Psychrometers consist of two thermometers; the bulb of one is encased in a cotton sleeve that is kept wet with distilled water (and is thus called a "wet bulb"). By swinging the sling psychrometer by the handle for two minutes, or by turning on the automated version, a Bendix Psychron, the temperature of the evaporating water is measured against the ambient room temperature (measured by the "dry bulb"). The less moisture in the air, the greater the rate of evaporation and the lower the temperature measured on the wet bulb. The two readings are located on a chart supplied by the manufacturer, and the relative humidity is extrapolated from those figures.

The *recording hygrothermograph* is called a *hair hygrometer*. Small bundles of human hair are stretched across two points. The hair responds to changes in the moisture content of the air, expanding in high humidity and contracting in low humidity. Levers moved by this expansion and contraction are attached to recording pens, which rest against moving graph paper, creating a constant record of changes. Generally, each graph covers a one-month period. The ambient temperature is recorded simultaneously on the graph. Hair hygrometers are less accurate than psychrometers. Indeed, they are calibrated using a psychrometer. Recording hygrothermographs are generally used in gallery and storage spaces of buildings with built-in environmental controls. The two psychrometers used in this experiment are non-recording types and are relatively inexpensive. They are used primarily for calibration in larger institutions and by smaller institutions for single readings on a regular basis, to establish trends and identify problems.

Materials and Apparatus

- sling psychrometer
- Bendix Psychron psychrometer
- recording hygrothermograph
- distilled water
- wet rags

Procedure

1. Calibrate the *recording hygrothermograph* by following these steps:
    a. Place a wet rag over the cage end of the hygrothermograph (the non-chart end). Let it sit for one hour and then remove the rag. The RH should read very close to 100%. This rejuvenates the hair, particularly when the hygrometer has been used in very dry conditions.
    b. A day (24 hours) after the cloth has been removed, the hairs on the recording hygrothermograph will have equilibrated. For comparison, take a reading with the Bendix Psychron psychrometer. Keep the sheathed bulb wet and let it run for two minutes. Take both wet and dry bulb temperature readings.
    c. Subtract the temperatures and locate the difference on the horizontal axis of the chart. Locate the dry bulb reading on the vertical axis. The %RH is found at the intersection of the two points.
    d. Compare the psychrometer reading with the recording hygrothermograph reading. If there is a discrepancy, adjust the relative humidity value of the hygrothermograph to that of the psychrometer. Adjust the temperature to the dry bulb reading from the psychrometer. This concludes the calibration procedure.
2. Place the hygrothermograph in a convenient spot and allow it to run undisturbed. Monitor the readings on a daily basis, using both the sling psychrometer and Bendix Psychron psychrometer. Record both psychrometer readings in chart form.
3. Continue to take daily psychrometer readings over a one-week period. Compare the two psychrometer readings for accuracy. Compare each of these two readings to the readings recorded on the hygrothermograph.

Questions

1. How do the readings from the two psychrometers and the recording hygrothermograph compare, following calibration of the hygrothermograph?
2. Calculate the percentage of inaccuracy of the least accurate RH measuring device, compared to the most accurate.

9.6 Experiment 2: Effect of Cycling Relative Humidity and Elevated Temperature on Photographs

Purpose

To observe the effects of cycling relative humidity and elevated temperature on film materials, as simulated by the Humidity-Cycling Adhesion Test outlined in ANSI/ASC Standard PH1.28-1984.

Introduction

Because of the complex multi-layered structure of photographic materials, cycling relative humidity can have a pronounced effect on their stability. Differential expansion and contraction (the wider the fluctuations the greater chances for damage) between the layers can result in damage to prints and negatives. Gradual seasonal changes, if moderate, will have a minimal effect on collections.

The Humidity-Cycling Adhesion Test, developed by ANSI, was devised to help determine the stability of photographic materials in uncontrolled environmental conditions. It is a qualitative test with no quantifiable results. It is used to observe the effect of cycling humidity on emulsion adhesion.

Materials and Apparatus

- paper samples: 21-step grey scales, processed for permanence (Experiment 15: 4.5.1)
- film samples: step tablets of 21 steps, processed for permanence (Experiment 15: 4.5.1)
- glass desiccator jars
- aging ovens
- saturated salt solutions:
  - potassium sulfate
  - lithium chloride monohydrate
- reflection densitometer
- transmission densitometer
- prepared Kodak Curve Plotting Graph Paper

Procedure

1. Mix two saturated salt solutions according to the instructions outlined in Section 2.6.1. Make approximately 300 mL each of potassium sulfate and lithium chloride monohydrate in water. Grades designated as "technical" or "purified" may be used.

2. Turn on the aging ovens and set the thermostat at 50°C. After two hours, check the temperatures on the oven thermometers. Adjust the temperature controls accordingly.

3. When the ovens have heated up, place the saturated salt solutions in the bottom of the two desiccators (one solution per desiccator). Apply vacuum grease to the lid seals and place them in the ovens to be "conditioned" for eight hours.

4. While the desiccators are being conditioned, select six paper samples that were prepared in Experiment 15: 4.5.1. Take visual and tricolor density readings of each step. Label each sample.

5. Select six film samples that were prepared in Experiment 15: 4.5.1. Take visual and tricolor density readings at each of the steps of the step tablet on each sample. Label each sample by cutting notches on the border.

6. Take one film sample and one paper sample. Place them in storage envelopes. Label them and set them aside to use as controls.

7. Take one of the metal desiccator hangers. Slide five paper and five film samples through the small punched holes onto the hanger. Place only one sample on each prong.

8. Remove the conditioned desiccator containing the potassium sulfate from the oven. Remove the lid and quickly insert the sample rack with the five film and five paper samples. Quickly replace the lid and return the desiccator to the oven for eight hours.

9. After eight hours, remove both desiccators from the oven. Remove the lids from both desiccators. Remove the sample rack from the desiccator containing the potassium sulfate solution. Place the rack in the desiccator containing the lithium chloride solution. Replace both lids and return the desiccators to the oven for 16 hours.

10. After the 16 hours, one cycle has been completed. Repeat the cycle a total of 12 times. For convenience's sake, it may be easiest to begin the cycle in the morning using the potassium sulfate solution, changing to the lithium chloride desiccator eight hours later, at the end of the day for the next 16-hour cycle.

11. After 12 cycles have been completed, remove the samples from the desiccator. Take visual and tricolor density readings of all samples and examine for any evidence of damage. Make notes as to the condition of the backing layer, or evidence of peeling, cracking, and flaking of the emulsion layer.

12. Average the five visual readings for both paper and film samples. Draw the characteristic curve for each on a piece of prepared graph paper.

13. On the same piece of graph paper, draw the characteristic curve of the averaged visual density readings from the samples before being subjected to the cycling test as outlined in Chapter 4.

Analysis

Write a report that describes any changes in density, color, or adhesion that occur among the various samples.

9.7 Experiment 3: Water Damage Test

Purpose

To carry out water damage testing on black-and-white and color photographic materials some of which have been specially treated with hardeners and to observe how some samples dry after prolonged soaking.

Introduction

When dry, the gelatin binder in photographs acts to protect both the silver halides before processing and the silver grains that result after exposure and development. When immersed in water, gelatin takes up water and swells. When removed from the water and dried, a gelatin layer will de-swell to roughly its previous thickness. It is this fact that makes it possible to expose a dry film in a camera, process it in aqueous solutions, and dry the film for later use.

When immersed in water for long periods of time, especially at elevated temperatures, gelatin will continue to absorb more and more water until the structural integrity of the gelatin layer is destroyed. When this happens, any image that was suspended inside the gelatin binder will also be destroyed. The time required to break up a gelatin layer in this way will depend on a number of variables, such as the nature of the gelatin itself, the pH of the water, and the temperature.

There are two circumstances of particular interest to conservators where prolonged immersion in water may occur. These are floods resulting from natural disasters or attempts to put out fires and from certain restoration treatments that require prolonged soaking of already deteriorated photographs in both alkali and acidic solutions.

This experiment is designed to investigate the effect of prolonged soaking in ordinary tap water and in a special alkali bath on four photographic materials. The experiment will also explore the effects of two pre-hardening treatments on the ability of the two black-and-white materials to resist being damaged by prolonged immersion.

Materials and Apparatus

- 2 24-exposure rolls of black-and-white photographic film
- black-and-white enlarging paper, 8" × 10", fibre-base
- 1 12-exposure roll of color negative film
- 35-mm camera
- Kodak Q-13 gray scale
- Macbeth Color Checker
- copyboard and lights
- manufacturer's developers for the black-and-white materials
- ANSI Non-Hardening Fixer
- Kodak fixer
- Kodak Special Hardener SH-1
- contact printing frame
- 6 trays for print processing
- print washer
- film processor or tank and reels
- 80 25-mL clear and colorless glass bottles
- 1 100-mL glass bottle
- parafilm
- freezer
- 10 heat sealable storage envelopes

Procedure

1. Set up the copyboard with the color checker and the grey scale so that the longer side of each target is butted up against the other. Set up the lights and a 35-mm camera as described in Chapter 6 to give even lighting and so that the camera film plane is parallel to the target. The length of the grey scale should just fit in the 35-mm film frame. Correctly expose the three rolls of film, paying particular attention that the color film is of the right type for the color temperature of the light sources or alternatively that the correct color compensating filters and adjusted exposure are used. Expose each frame using the correct exposure of each roll.
2. Send the color negative film out for processing to a laboratory that is also capable of contact printing the results on color paper. The lab must be willing to do this with the negatives and print material in true contact and not with the negatives in a plastic sleeve.
3. Process the black-and-white negatives following the manufacturer's recommendations with one exception. Process one of the rolls using the ANSI non-hardening fixer and process the other using Kodak fixer. Follow the manufacturer's recommended fixing, hypo clearing, and washing times in each case. Do not wash the two films together. Label each roll.
4. Using one of the black-and-white rolls determine, by making test contact prints, the best exposure for the paper type being used. Use the manufacturer's recommended chemicals for processing. When the best exposure has been determined, expose and process one sheet and develop it according to the manufacturer's recommendation. Fix this sheet for 10 minutes with intermittent agitation in Kodak fixer. Rinse, hypo clear, and wash the sheet according to the manufacturer's directions. If these are not available, rinse for 30 seconds in running water, hypo clear for 3 minutes, and wash for 30 minutes. Dry the print face down on a drying screen. Make the second print in an identical manner to the first but substitute the ANSI non-hardening fixer in place of the Kodak fixer. Lightly label both sheets with an HB pencil on the back.
5. Cut each of the two black-and-white prints in half so that there are 12 images on either side. Make sure that each half is labelled. Prepare the solution of Kodak Special Hardener SH-1 according to the following formula. This must be done in a fumehood while wearing protective eye wear and neoprene gloves.

Distilled water	500 mL
Formaldehyde (approx. 37% solution)	10 mL
Sodium carbonate (monohydrated)	6 grams
Distilled water to make	1000 mL

In the fumehood, pour a sufficient quantity for soaking two prints into an 8" × 10" tray. Immerse one piece of black-and-white paper fixed in Kodak fixer and one fixed in the non-hardening fixer for three minutes. Rinse both prints for 30 seconds in running water and refix them for five minutes each in the same fixer they were originally fixed in. Wash each print separately for 30 minutes. Repeat this process with half of each of the two rolls of black-and-white film.

6. Prepare one liter of an alkali soaking bath solution as follows:

Distilled water	900 mL
Sodium carbonate, anhydrous	25 grams
Distilled water to make	1000 mL

7. The following materials should now be ready for soaking:

color negatives	12 frames
color prints	12 frames
black-and-white negatives, ANSI fix	12 frames
black-and-white negatives, Kodak fixer fix	12 frames
black-and-white negatives, SH-1 and ANSI fix	12 frames
black-and-white negatives, SH-1 and Kodak fixer fix	12 frames
black-and-white prints, ANSI fix	12 frames
black-and-white prints, Kodak fixer fix	12 frames
black-and-white prints, SH-1 and ANSI fix	12 frames
black-and-white prints, SH-1 and Kodak fixer fix	12 frames

Label each frame using a notching technique for the films and an HB pencil on the back of the paper prints. Record visual and tricolor density values for a D-min, mid-tone, and D-max value for each color frame. Record visual densities for D-min, mid-tone, and D-max densities for each black-and-white frame. Fill 40 25-mL glass bottles with tap water and 40 25-mL bottles with the alkali solution. Bottles should be filled to very near the top so that samples placed in them will bring the fluid level in the bottle to just below overflowing. From each sample group, cut out eight individual frames. Place four of the frames into four individual water bottles and close them with parafilm. Immerse the remaining four samples in the alkali solution, one per bottle, and close the bottles with parafilm. Samples may be rolled somewhat, emulsion side on the inside of the roll in order to fit them into the neck of the bottle. Label every bottle with a small label that does not obscure the view of the sample and set them all aside. The bottles are to be left undisturbed at 21°C or greater. Observe each bottle twice a day, looking for signs of damage and taking note of any changes that occur. After one week, it is necessary to check the bottles only once a day. After three weeks, remove the samples from the bottles. Rinse the samples from the alkali solutions gently with distilled water for 30 seconds and hang all the samples up to dry. Where it is possible to do so, take density readings of the same steps measured before immersion.

8. Fill one 100-mL bottle with tap water. Immerse three sample frames of each of the 10 groups listed in step 7, reserving one sample from each group as a visual control. Agitate the samples until all the air bells on the samples are gone. Top up the bottle so that it is entirely full of tap water and seal it using parafilm. Allow the bottle to sit at room temperature for 48 hours.
9. After 48 hours, remove the samples and place two of each type into the heat sealable envelope. Fold over the open end of the envelope and place it in a freezer. Hang up the remaining samples to air dry using stainless steel or plastic clips.
10. After 48 hours, remove the frozen samples from the freezer and allow them to come up to room temperature for one hour. Remove them from the envelope, rinse them in a distilled water bath for 30 seconds, and hang them up to dry.
11. Measure the densities of the air dried and frozen-thawed-air dried samples in the same places where their densities were originally measured. Record any differences in appearance between the samples that were frozen and those that were not.

Analysis

Write a brief report describing which samples were destroyed by prolonged soaking and when signs of deterioration were first noticed. Distinguish between deterioration within 1 mm of the sample's edge and damage in the center of the sample. Report any relationships between sample type and deterioration and between hardening treatments and deterioration. Also note any visual or density differences between samples that were frozen-thawed-air dried and those that were simply air dried.

Questions

1. Why was an alkali solution used as a second soaking environment?
2. What general conclusions can be made regarding the stability of these modern materials after prolonged soaking?

9.8 Display Conditions for Photographs

It is a fundamental mandate of institutions that collect historical documents to make the holdings available for enjoyment, study, and research. A common means to do this is an exhibition. Although some objects in museums may be on what is called permanent display, exhibitions of pictures are generally of short duration, i.e., from several weeks to a few months, rarely exceeding one half year. Display conditions in museums with respect to light, humidity, and air pollution have been discussed exhaustively by Thomson (1986), but the author's deliberations do not include photographs. In most institutions, the decision to display materials is made jointly between curators, conservators and exhibition staff, so the photograph conservator should be prepared to specify conditions of display for any given type of photograph collection and to justify their recommendations.

Our considerations begin at a stage where it has been decided that a photograph needs conservation treatment before being exhibited and that it is stable enough to withstand the handling necessary to mat, frame, and transport it. Display conditions for photography which must now be determined are defined by:

- the concentration of chemically aggressive contaminants in the air;
- the level of relative humidity;
- the temperature; and
- the illuminance.

The first three parameters should be the same as discussed in a previous section of this chapter on storage conditions. Since oxidizing chemicals are the most immediate threat to the stability of black-and-white photographs, their presence must be avoided by providing an environment where sulfur dioxide (SO_2) is $\leq 1 \mu g/m^3$; nitrogen oxides (NO_x) are $\leq 5 \mu g/m^3$ (Mathey, et al., 1983). Thomson (1986) allows higher values for SO_2 and NO_2 (i.e., $\leq 10 \mu g/m^3$ for both) but a lower value for ozone: $\leq 2 \mu g/m^3$. The temperature in an exhibition space should be kept between 20°C and 24°C. Daily cycling of more than 4-6°C must be avoided. Relative humidity, which increases the rate of so many chemical reactions, should be at 35 to 40% ± 3%. Consistency in its level is also essential here.

The most careful consideration, however, must be given to the effects of light on a photograph. They depend upon a number of variables, the most important of which are:

- the type of photograph;
- the type of light source;
- the illuminance level;
- the duration of the exhibition;
- the absence (or presence) of a glass sheet between the light source and the photograph;
- the artist's desired illuminance level for viewing;
- the illuminance level needed for correct perception of detail and color.

Some photographers intend their images to be viewed at certain light levels (Adams, 1983). If such intentions are known, exhibition organizers may want to adjust light levels accordingly. Aesthetic reasons demand a light level high enough to perceive subtle color differences and shadow details in a photograph in a satisfactory manner. Hunt (1975) has pointed out the need for conditions of high illumination in order to appreciate the appearance of color prints. Good indoor daylight is necessary to produce the perception of clear, brilliant whites. Hunt also demonstrated that an increased illumination level improves luminosity (i.e., visual response of an observer) and leads to substantial increase in color saturation. A standard illumination level for judging and exhibiting reflection prints, published by ANSI, recommends 800 lux ± 200 lux (ANSI, 1989).

Of the many existing light sources, tungsten filament lamps (incandescent light bulb), tungsten halogen lamps (sometimes called quartz iodine lamps), fluorescent lamps, and daylight are the most common. Since daylight is difficult to control because it changes its properties throughout a day, it is rarely used in exhibitions. Photographs must be *prevented from exposure to direct sunlight* under any circumstances, because of its high illuminance (up to 12,000 footcandles) and its rich ultra-violet (UV) content. The preferred light sources to illuminate photographic images are tungsten filament lamps and tungsten halogen lamps, although fluorescent lamps must sometimes be used when photographs are displayed in hallways, offices, and working areas.

The type of photograph to be displayed will further determine the illuminance level of an exhibition. Well-processed black-and-white prints on fibre-base paper are essentially stable to light and heat. Their stability is increased if they have been toned for protection (see also Chapter 4). There are no accounts in the literature of such prints having suffered damage during an exhibition through the action of light alone. Empirical reports of such happenings were almost certainly caused by the presence of reactive substances capable of oxidizing image silver. Photographic manufacturers, always careful in giving assurances about the stability of their materials, have not issued any warnings about the effect of light on black-and-white photographs. A publication entitled *Conservation of Photographs* (Eastman Kodak, 1985a) states:

> "Light has no significant effect upon the silver of an image in ordinary circumstances. However, light can reduce ions to metallic silver after oxidizing gases and moisture have acted upon the image as described above."

Another industry publication (Eastman Kodak, 1985b) has this to say:

> "Apparently light and ultraviolet radiation have no effect on the longevity of black-and-white print images that have been properly toned as above. The prints can be displayed or kept in the dark with no difference in image stability. Untoned prints exposed to high levels of radiation for long periods of time may show image changes.
>
> Such radiation seems to have little effect on the base of prints made on fiber-base papers. Processed and toned as indicated in the previ-

ous section, prints made on fiber-base papers can be expected to last for generations, whether they are displayed or not."

Any exhibition is a valuable occasion to increase our knowledge about fading rates in museums. This can be done for photographs by displaying a fading monitor along with the exhibition items. A fading monitor is a grey scale, or color scale, made from the same material and under the same conditions as the exhibition print, and it is displayed under the same condition. If, for example, all photographs in an exhibition are made on brand X paper manufactured by company Y, then the fading monitor is made on that same paper and framed and glazed like the exhibition prints. This has been proposed and extensively discussed by Wilhelm (1981). If exhibitions were used regularly as an occasion to monitor print fading in this way, valuable data on the light stability of photographic prints would result. One such case of monitoring has been described by Severson (1987). Density changes of 180 photographs were measured after a display of nine weeks under tungsten light of an illuminance of "less than 30 footcandles" (approximately 300 lux). Significantly, none of the prints on silver gelatin developing-out paper showed any density changes. All indications are that black-and-white prints from the category noted above can safely be exposed at illuminance levels between 500 lux and 1000 lux. This recommendation is made provided there is clean air in the display area and both temperature and relative humidity are controlled and stable.

Notes on Table 9.6:

Data on light fading are usually obtained from pure dye patches as compared to neutral grey areas, which would contain approximately equal amounts of yellow, cyan, and magenta dyes. Fading data supplied by manufacturers were obtained from pure dye patches, whereas data from the Preservation Publishing Company were obtained from neutral grey areas. Fading rates obtained from pure dye patches are higher than those from neutral grey areas. The end point is indicated as a loss of 0.3 density units of the limiting (i.e., the weakest) dye. Starting density is at 1.0. Note the different illuminance levels for data by Fuji Photo Film Co. Ltd. and by Ilford Photo Corp. Note further that all values for times to reach the end point are obtained by extrapolation from data obtained at higher illuminance levels. The data supplied by the manufacturing industry are much more conservative than those obtained by outside tests. Industry data seem to present a worst case scenario. The sole purpose of publishing these data is as a basis for a discussion of acceptable light levels for the display of color photographs. The term acceptable is meant here to indicate a compromise between light levels sufficiently high to view a photograph, yet low enough to protect the photograph from damage by light.

Table 9.6: Light Fading Rates for some Contemporary Color Print Materials: Loss of Density by the Limiting Dye from 1.0 Starting Density

Color Print Material	Illuminance [Lux]	Duration of Exposure	End Point	Time to Reach End Point
Ektacolor Plus and Ektacolor 2001 [1]	300 [a]	10 hrs./day 6 days/week	Loss of 3/10 density units	22 years
Ektacolor Plus [2]	300 [b]	10 hrs./day 6 days/week	Loss of 3/10 density units	24 years
Fuji Paper Super FA [3]	300 [c]	12 hrs./day 6 days/week	Loss of 3/10 density units	18 years
Agfacolor Type 9 Paper [4]	300 [d]	10 hrs./day 6 days/week	Loss of 3/10 density units	23 years
Kodak Dye Transfer [2]	300 [b]	10 hrs./day 6 days/week	Loss of 3/10 density units	41 years
Ilford Cibachrome [5]	300 [e]	10 hrs./day 6 days/week	Loss of 3/10 density units	25 years
Ilford Cibachrome [2]	300 [b]	10 hrs./day 6 days/week	Loss of 3/10 density units	43 years

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1. Source: Eastman Kodak Company (1987).
2. Source: Preservation Publishing Company (1989).
3. Source: Fuji Photo Film Co. Ltd. (1989).
4. Source: Agfa-Gevaert AG (1989).
5. Source: Ilford Photo Corporation (1988).

a. Tungsten or fluorescent; extrapolated from data obtained at 5.4 Klux.
b. Fluorescent light; extrapolated from data obtained at 1.35 Klux.
c. Xenon Arc light; extrapolated from data obtained at 85 Klux.
d. Fluorescent light; extrapolated from data obtained at 10 Klux.
e. Xenon Arc light; extrapolated from data obtained at 100 Klux.

Recommendations for light levels when displaying black-and-white prints made by other processes (i.e., those on printed-out papers: salted prints, albumen prints, silver gelatin printing-out paper) are more difficult to make. There is almost a complete lack of data about their response to light. Severson (1987) reported that of 16 albumen prints in the exhibition, six showed no changes at all, while the remaining prints, with one exception, showed density increases. A calotype negative by W.H.F. Talbot showed no changes. Yet it is often assumed that the very early paper photographs may have been processed with less knowledge and care than is available today and so render them susceptible to the effects of light. In such cases of uncertainty, illuminance levels can be controlled by innovative methods of print display. For example, a black felt cloth can be draped over a photograph on display. The viewer lifts the felt in order to see the picture. Photographs have been displayed in exhibition cases fitted with hinged covers. When the viewer opens the cover, a light above the case is switched on automatically. Such display arrangements can be modified according to requirements posed by a specific photograph, institutional policy, and readiness of conservators and curators to find new ways of showing photographs without subjecting them to potentially damaging influences. Further examples: a photographic print may be kept, while on exhibition, in a drawer; the viewer must open the drawer to see it. Individual spot lights can be used to illuminate a photograph, as is often done in commercial galleries: their intensity may be controlled by a dimmer switch. More variations of such methods could be mentioned. In rare cases, when all contributors to an exhibition agree that an original photograph is too fragile to be put on display, a copy photograph should be prepared and substituted for the original.

When considering the display of color photographic prints, we begin our discussion with a look at contemporary materials. Color photographic prints have reached an unprecedented level of stability when compared to those made in the early days of color photography four or five decades ago. Photographic manufacturers are reluctant to publish actual fading data of color photographic products, because there are so many variables involved in carrying out fading tests. The tests are performed using complex equipment under rigidly controlled conditions with samples made from a certain emulsion batch. These conditions may vary in another testing laboratory with the consequence of different results. The variability of fading data resulting from different test laboratories and conditions should be kept in mind when interpreting fading data. Table 9.6 shows light fading rates for some current color print materials coming from different sources. The times to reach a certain end point in the fading process are of the same order of magnitude. It is also noteworthy that the fading times obtained by non-industry tests are slightly higher. The manufacturing industry often underestimates the light stability of their products. In order to be able to perceive colors in photographs on display, an illuminance level of 300 lux is recommended. The data in Table 9.6 show, for example, that a current, well-processed print on Ektacolor Plus Paper could be exhibited about 60 times, for a display duration of three months each time, before the limiting dye reached an end point of 3/10 density loss! Other color print papers show similar behavior. The end point of 3/10 loss of density of the limiting dye is, of course, chosen arbitrarily. A 10% density loss is not noticeable by the human eye without a reference point. If neutral fading occurs, i.e., all three dyes fade at the same rate, it would be difficult for the human eye to recognize a 3/10 loss of density without a reference point. Since one dye, the limiting dye, usually loses density faster than the other two, a color shift is produced that is easily recognizable. The data in Table 9.6 confirm that an illuminance level of 300 lux for the purpose of display for a limited period of time is a reasonable compromise between requirements to satisfactorily view a print and the need for its preservation.

Exhibiting older color prints may require more difficult decisions. Fading rates for older materials are generally not available. Many of them will show signs of a color shift: for example, those that have been exposed to light for too long may show a cyan (blue-green) cast, while older chromogenic color prints that have been kept in the dark may have acquired an overall warm reddish color. Such photographs should not be displayed at all. Instead, copy prints can be prepared for exhibition purposes.

It should become standard practice to monitor densities of black-and-white prints and color prints by comparing measurements in highlight areas, mid-tones, and shadow regions before they go on display, with values obtained after exhibition. This practice is particularly useful for prints on loan to other institutions. Complete condition reports, including density readings of photographic prints before and after an exhibition period, are the only sure way to determine whether image changes have occurred.

9.9 Standards

Soon after the development of photography on paper, practitioners in scientific and art journals expressed concern about the stability of these images, particularly about the problem of fading. Customers who sat for photographs and watched them deteriorate soon after paying for them expressed their dissatisfaction in the popular press. As early as 1855, a "Committee Appointed to Take Into Consideration the Question of the Fading of Positive Photographic Pictures Upon Paper" by the Royal Photographic Society in London, England, published its finding after studying the effects of certain chemicals and environmental factors on the stability of photographs on paper (Delamotte, 1855).

As photography became an activity for amateurs in the 1880s, the consumption of photographic film and paper increased tremendously. This burgeoning use of photography to record anything and everything has continued so that it is impossible to conceive the number of exposures made and prints produced each year. Much of our history has been recorded in this medium over the last century and a half.

That those historical documents exist today speaks well of 19th-century concerns for permanence and early efforts to introduce standards for this medium. Today, standards are developed nationally and internationally, for nearly every aspect of photography except picture content. They guide the manufacturing of the materials, the use of proper processing procedures, and the judicious storage and display of photographic materials, among other issues. In the face of litigation over the loss of pictures assumed by the consumer to be permanent, it is to the industry's advantage to adhere to recommended standards. Industry itself has contributed to the setting of such standards, as it strives to understand the mechanisms of deterioration of photographic materials.

Photograph conservation has benefitted from the development of standards and from research carried out by manufacturers. Although conservators may be called upon to advise in-house photographic laboratories about appropriate products and sound processing methods, their larger concern is for the preservation of photographs made elsewhere by photographers and laboratories whose methods were unknown to the custodial institution. A clear understanding of standards of quality and permanence for modern photographic products gives us a point of comparison for older products. Industry-generated research into the mechanisms that cause modern materials to deteriorate, and the conditions that instigate or exacerbate these mechanisms, can be applied to the development and implementation of conservation treatment methods and preventative storage procedures.

The most widely used standards in North America are written by ANSI, which engages committees of experts to formulate particular standards. These standards are frequently revised as new information becomes available and new products appear on the market. Corresponding standards are developed by the British Standards Institution, the Canadian Standards Association, and the International Organization for Standardization.

Because of the fire risk associated with storage of cellulose nitrate motion picture film, the U.S. National Fire Protection Association has developed standards for the storage and handling of these films, NFPA No. 40, which governs building requirements, ventilation, and storage temperature.

A complete list of standards referred to in this study guide will be found in the Bibliography.

9.10 References

Adams, Ansel. 1983. *The Print*. New Ansel Adams Photography Series, book 3. Boston: Little, Brown.

Agfa-Gevaert. 1989. Letter to author, 19 January 1990.

ANSI. 1985. *American National Standard for Photography Film — Processed Safety Film — Storage* ANSI PH1.43-1985. New York: American National Standards Institute.

ANSI. 1988a. *Photographic Processed Films, Plates, and Papers — Filing Enclosures and Storage Containers*. ANSI IT9.2-1988. New York: American National Standards Institute.

ANSI. 1988b. *Ammonia-Processed Diazo Films — Specifications for Stability*. ANSI IT9.5-1988. New York: American National Standards Institute.

ANSI. 1989. *American National Standard for Graphic Arts and Photography — Color Prints, Transparencies, and Photomechanical Reproductions — Viewing Conditions*. ANSI PH2.30-1989. New York: American National Standards Institute.

Carroll, J.F., and J.M. Calhoun. 1955. Effects of Nitrogen Oxide Gases on Processed Acetate Film. *Journal of the Society of Motion Picture and Television Engineers* **64**: 501-507.

Constable, W.G. 1934. Appendix III: Framing and the Control of Humidity. In *Some Notes on Atmospheric Humidity in Relation to Works of Art*, 39-42. London: Courtauld Institute of Art.

Delamotte, P.H., et al. 1855. First Report of the Committee Appointed to Take Into Consideration the Question of the Fading of Positive Photographic Pictures Upon Paper. *Journal of the Photographic Society* (London) **2**(36): 251-252.

Eastman Kodak. 1983. *Storage and Preservation of Microfilms*. Kodak Publication, no. D-31. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1985a. *Conservation of Photographs*. Kodak Publication, no. F-40. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1985b. *Quality Enlarging with Kodak B/W Papers*. Kodak Publication, no. G-1. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1987. *Paper Information from Kodak: Kodak Ektacolor Plus and Professional Papers for the Professional Finisher*. Kodak Publication, no. E-18. Rochester, N.Y.: Eastman Kodak Co.

Eaton, G.T. 1987. History of Processing and Image Stability. In *Pioneers of Photography: Their Achievements in Science and Technology*. Eugene Ostroff, ed., 87-93. Springfield, VA: SPSE.

Feldman, L.H. 1981. Discoloration of Black-and-white Photographic Prints. *Journal of Applied Photographic Engineering* **7**(1): 1-9.

Fuji Photo Film. 1989. *Fuji Film Data Sheet: Fujicolor Paper Super FA*. Publication AF-3-615E. Tokyo: Fuji Photo Film Co. Ltd.

Haynes, R. 1981. Emergency Storage for Nitrate Film: Conservation Tips. *History News* **36**(1): 38-41.

Hendriks, Klaus B. 1984. *The Preservation and Restoration of Photographic Materials in Archives and Libraries: A RAMP Study With Guidelines.* Paris: Records and Archives Management Program, UNESCO.

Hendriks, Klaus B. 1987. Notes on Microfilm. *Archivaria* **23**: 179-184.

Hendriks, Klaus B. 1989. The Stability and Preservation of Recorded Images. In *Imaging Processes and Materials: Neblette's Eighth Edition*, ed. by John Sturge, Vivian Walworth and Allan Shepp, 637-684. New York: Van Nostrand Reinhold.

Hendriks, Klaus B., and B. Lesser. 1983. Disaster Preparedness and Recovery: Photographic Materials. *American Archivist* **46**(1): 52-68.

Henn, R.W., and I.A. Olivares. 1960. Tropical Storage of Processed Negatives. *Photographic Science and Engineering* **4**(4): 229-233.

Henn, R.W., et al. 1965. Microscopic Spots in Processed Microfilm: The Effect of Iodide. *Photographic Science and Engineering* **9**(3): 167-173.

Hunt, R.W.G. 1975. Reflection Prints in Colour. In *The Reproduction of Colour.* 3rd ed., by R.W.G. Hunt, 208-221. Kings Langley, Herts.: Fountain Press.

Ilford. 1988. *Mounting and Laminating: Cibachrome Display Print Materials and Films.* Paramus, N.J.: Ilford Photo Corporation.

Kopperl, D.F., and C.C. Bard. 1985. Freeze/Thaw Cycling of Motion-Picture Films. *Society of Motion-Picture and Television Engineers Journal* **94**(8): 826-827.

Lafontaine, R. 1981. *Environmental Norms for Canadian Museums, Art Galleries and Archives.* Canadian Conservation Institute Technical Bulletin, no. 5. Ottawa: CCI.

MacIntyre, J.A. 1934. Air Conditioning for Mantegna's Cartoons at Hampton Court Palace. *Technical Studies in the Field of the Fine Arts* **2**(4): 171-184.

MacLeod, K.J. 1978. *Relative Humidity: Its Importance, Measurement and Control in Museums.* Canadian Conservation Institute Technical Bulletin, no. 1. Ottawa: CCI.

Mathey, R.G., et al. 1983. *Air Quality Criteria for Storage of Paper-based Archival Records.* NBSIR, nos. 83-2767 and 83-2770. Washington, D.C.: National Bureau of Standards, National Archives and Record Service.

McCamy, C.S., and C.I. Pope. 1970. Redox Blemishes — Their Cause and Prevention. *Journal of Micrographics* **3**(4): 165-170.

Michalski, Stephen. 1987. *Display Cases.* Draft version of a Canadian Conservation Institute Technical Bulletin, in preparation.

National Archives of Canada. 1989. *Headquarters Accommodation Program: Requirements Statement for the National Archives of Canada Headquarters Accommodation.* Ottawa: NAC.

Pope, C.I. 1963. Determination of Residual Thiosulfate in Processed Microfilm. *Journal of Research of the National Bureau of Standards* **67**(3): 15-24.

Preservation Publishing Company. 1989. Personal communication from H. Wilhelm. Data to be published by Preservation Publishing Company.

Reilly, J.M. 1982. Albumen Prints: A Summary of New Research About Their Preservation. *Picturescope*, Spring, 36.

Reilly, J.M. 1986. *Care and Identification of 19th-Century Photographic Prints*. Kodak Publication, no. G-2S. Rochester, N.Y.: Eastman Kodak Co.

Reilly, J.M., et al. 1988. *Photo Enclosures Research and Specifications*. Paper presented at the National Archives and Records Administration Conference, April 12, 1988, Washington, D.C.

Sack, Susanne P., and Nathan Stolow. 1978. A Micro-climate for a Fayum Painting. *Studies in Conservation* **23**(2): 47-56.

Severson, D.G. 1987. The Effects of Exhibition on Photographs. *Picturescope* **32**(4): 133-135.

Thomson, G. 1986. *The Museum Environment*. 2nd ed. London: Butterworths.

Tuite, R.J. 1979. Image Stability in Color Photography. *Journal of Applied Photographic Engineering* **5**(4): 200-207.

Widmayer, W. 1961. Cold Storage Protects Colour Negatives. *American Cinematographer* **42**: 170-172, 174.

Wilhelm, H. 1978. Storing Colour Materials; Frost Free Refrigerators Offer a Low-Cost Solution. *Industrial Photography* **27**(10): 32.

Wilhelm, H. 1981. Monitoring the Fading and Staining of Colour Prints. *Journal of the AIC* **21**: 49-64.

Williams, R.S. 1985. Problems with Commercial Storage and Filing Enclosures for Processed Photographic Materials: Chemical Analysis and Recommendations for Suitable Procedures and Materials for Museum and Archival Storage Purposes. In *Printing of Transcript Summaries: Society of Photographic Scientists and Engineers, Second International Symposium, The Stability and Preservation of Photographic Images, August 25-28, 1985, Ottawa*, 16-30. Ottawa: SPSE.

Wilson, William K., and Carl J. Wessel. 1984. *Guidelines for Environmental Conditions in Archives and Libraries*. National Archives and Records Service Technical Report. Washington, D.C.: National Institute for Conservation.

9.11 Supplemental Readings

Anon. 1981. Calm, Very Cool and Collected ... To Save Film Legacies. *Technology and Conservation* **6**(1): 5-6, 8.

Adelstein, P.Z., et al. 1970. Preservation of Motion-Picture Color Films Having Permanent Value. *Journal of the Society of Motion Picture and Television Engineers* **79**: 1011-1018.

Avedon, D. 1972. Standards: Microfilm Permanence and Archival Quality. *Journal of Micrographics* **6**(2): 93-94.

Avedon, D. 1978. Archival Quality and Permanence of Microfilm. *I.M.C. Journal* **1**(2): 12-14.

Avedon, D. 1978. Micrographic Standards Worldwide. *I.M.C. Journal* 1(3): 11-16.

Bohem, H. 1975. A Seam-free Envelope for Archival Storage of Photographic Negatives. *American Archivist* 38(3): 403-405.

Calhoun, J.M. 1952. Cold Storage of Photographic Film. *Photographic Society of America Journal* **18B**(3): 1-4.

Colton, E.K., and E.J. Wiegand. 1950. Moisture in Photographic Film and Its Measurement. *Photographic Science and Engineering* 2(3): 170-176.

Cooney, J.D., and D.M. Wiles. 1981. *Proposed Standard Specifications for Electrophotographic Film for Archival Records, Organic Photoconductor Type, on Polyester Base.* Special Report. Ottawa: National Research Council.

Couprie, S., et al. 1970. Increase of Density of the Silver Image During Storage After Processing. *Journal of Photographic Science* **18**: 159-160.

Craddock, A.B. 1984. *Control of Temperature and Humidity in Small Institutions.* New York State Conservation Consultancy Bulletin.

Dorfman, H. 1976. Film Preservation. *Microfilm Techniques* **5**(6): 7, 10, 12, 21.

Fisher-Taylor, G. 1979. Care and Processing of Archival Black-and-White Prints. *Printletter 19* **4**(1): 16-17.

Gillet, M., Garnier, C., and Flieder, F. 1981. Influence de l'environnement sur la conservation des documents photographiques modernes [Environmental Influence on the Conservation of Modern Photographic Documents]. In *Les documents graphiques et photographiques : analyse et conservation,* 39-109. Paris: Édition du Centre National de la Recherche Scientifique.

Hickman, M.J. 1970. *Measurement of Humidity.* 4th ed. Notes on Applied Science, no. 4. London: Natural Physics Laboratory.

Karp, C. 1983. Calculating Atmospheric Humidity. *Studies in Conservation* **28**(1): 24-28.

Karr, Laurence F., ed. 1980. *Proceedings: Conference on the Cold Storage of Motion Picture Films, April 21-23.* Washington, D.C.: American Film Institute and Library of Congress.

Lafontaine, R. 1981. *Recommended Environmental Monitors for Museums, Archives, and Art Galleries.* Canadian Conservation Institute Technical Bulletin, no. 3. Ottawa: CCI.

Lull, W.P., and L.E. Merk. 1982. Lighting for Storage of Museum Collections: Developing a System for Safekeeping of Light-sensitive Materials. *Technology and Conservation* **7**(2): 20-25.

Padfield, T. 1966. The Control of Relative Humidity and Air Pollution in Show-cases and Picture Frames. *Studies in Conservation* **11**(1): 8-30.

Powers, S. 1978. Why Exhibit? The Risks Versus the Benefits. *American Archivist* 41(3): 297-306.

Reilly, J.M., et al. 1982. Image Deterioration in Albumen Photographic Prints. In *Science and Technology in the Service of Conservation, 1982, IIC Preprints*, 61-65. London: International Institute for Conservation of Historic and Artistic Works.

Runyan, I.V. 1956. The Aging of Photographic Film Products. *Photographic Engineering* 7(2): 111-117.

Schwalberg, Bob, Henry Wilhelm and Carol Brower. 1990. Going! Going!! Gone!!!. *Popular Photography* 97(6): 37-49, 60.

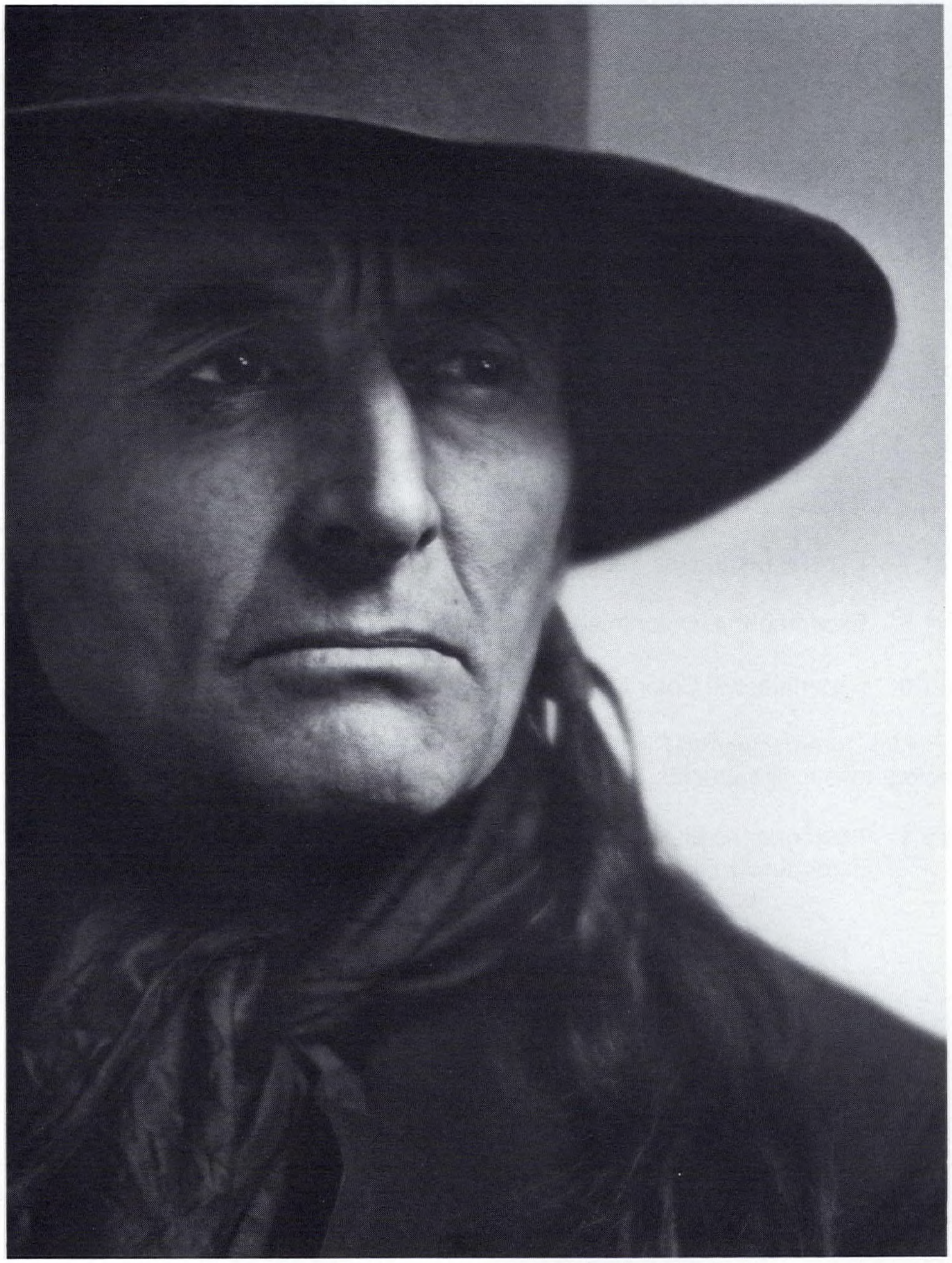
Scribner, B.W. 1939. Summary Report of Research at the National Bureau of Standards on the Stability and Preservation of Records on Photographic Film. *The Journal of Research of the National Bureau of Standards* (Washington, D.C.), Nov. 16, 1-17.

Smith, T.D. 1953. The Effect of Environment on the Aging of Photographic Film. *Journal of Photographic Science* 1: 138-144.

Thomson, G. 1964. Relative Humidity: Variation with Temperature in a Case Containing Wood. *Studies in Conservation* 9(4): 153-168

Wiederhold, P.R. 1975. Humidity Measurements. *Instrumentation Technology*, Oct. Reprint. Watertown, Mass.: General Eastern Instruments Corp.

Grey Owl (Archibald Belaney) (1888-1938). Ottawa, Ontario. 1937. Yousuf Karsh. Contemporary print from original negative.



10 Tests for Image Stability and Suitability of Conservation Materials

10.1 Procedures for Image Stability Testing

- 10.1.1 Image Stability: Introduction
- 10.1.2 Experiment 1: Black-and-White Image Stability Test
- 10.1.3 Experiment 2: Black-and-White Light Fading Test
- 10.1.4 Experiment 3: Gas Fading Test
- 10.1.5 Experiment 4: Color Image Stability Test
- 10.1.6 Experiment 5: Color Light Fading Test

10.2 Tests for Determining the Response of Photographs to Treatments

- 10.2.1 Photographic Materials Testing: Introduction
- 10.2.2 Experiment 6: Melting Point Test
- 10.2.3 Experiment 7: Swelling Test
- 10.2.4 Experiment 8: Scratch Resistance Test
- 10.2.5 Experiment 9: Wet Abrasion (Mushiness) Test

10.3 Tests for the Suitability of Materials Used in the Conservation of Photographs

- 10.3.1 Tests of Conservation Materials: Introduction
- 10.3.2 Experiment 10: Photographic Activity Test

10.4 References

10.5 Supplemental Readings

10.1 Procedures for Image Stability Testing

Throughout this study guide, several kinds of tests have been described. These have primarily been tests relating to the processing of photographic materials and tests to identify various historical and contemporary photographs. Many of these tests are listed below.

1. Tests relating to the processing of photographic materials.

   a. Testing of processing chemicals for exhaustion:

   Fixing bath: Kodak Fixer Test Solution FT-1
   Stop bath: Kodak Stop Bath Test Solution
   SBT-1 Indicator Stop Bath

   b. Testing of processed contemporary samples for residual thiosulfates and silver:

   Residual hypo: Kodak Hypo Test Solution HT-2
   Methylene Blue Method
   Silver Densitometric Method

   Residual silver: Kodak Residual Silver Test Solution ST-1
   Kodak Rapid Selenium Toner
   ANSI Test for Silver Compounds

2. Test to identify various 19th- and 20th-century photographic processes.

   Alcohol test for collodion emulsions
   Water drop test for gelatin materials
   Nitrate-base film tests:
     ANSI Burn Test
     Float test in trichloroethylene
   Float test for cellulose triacetate-base film
   Float test for polyester-base film
   Polarization test for polyester/cellulose triacetate-base films

In this chapter we will concentrate more on testing the properties of photographic materials themselves. This will include testing the image stability of several black-and-white and color materials and examining some of the more relevant physical properties of gelatin layers such as melting point, swelling, and resistance to abrasion. Testing of photographic storage materials will also be described. The tests described in this chapter are listed below.

1. Image stability tests.
   - Black-and-white: Image Stability Test
     Light Fading Test
     Gas Fading Test
   - Color: Image Stability Test
     Light Fading Test
2. Photographic materials tests.
   - Melting Point Test
   - Swelling Test
   - Scratch Resistance Test
   - Wet Abrasion (Mushiness) Test
3. Tests for the suitability of materials used in the storage and conservation of photographs.
   - Photographic Activity Test

The utility of these tests and experiments depends on the design of the test itself, the care taken by the experimenter to perform the test accurately and consistently, and the accuracy and degree of precision offered by the various pieces of equipment used in each test. Almost all of the tests to be performed in this chapter were developed or adopted by the committees for photographic materials of the ANSI. All test procedures must be followed exactly. Any "short cuts" or alterations in procedures may invalidate the results, making it necessary to repeat the experiment. Only consistent procedures allow for reproducible results. Students should review standard processing procedures, should be careful to use only clean glassware and fresh, uncontaminated chemicals, and should regularly calibrate equipment (such as thermostats on ovens and densitometers). Procedures for the preparation and labelling of samples used in these tests, and for the compilation and analysis of experimental data, are discussed in Chapter 2. Finally, almost all of these experiments assume the student has read a copy of the relevant ANSI standard for each experiment.

10.1.1 Image Stability: Introduction

It is generally acknowledged that the support layer of a photograph and the binding medium (emulsion) are more stable chemically than the image-forming substance, whether it be metallic silver or chromogenic dyes. The five experiments in this section are designed to test the reaction of the image-forming substance to accelerated aging, oxidizing gases, and the action of light. The aging of materials, their susceptibility to oxidizing agents and their stability while on display are all areas of concern for photograph conservators and for archivists responsible for photographic materials.

10.1.2 Experiment 1: Black-and-White Image Stability Test

Purpose

To perform the ANSI Image Stability Test, as outlined in ANSI PH1.41-1984, *for Photography (Film) — Archival Records, Silver-Gelatin Type, on Polyester Base,* and ANSI PH1.28-1984, *for Photography (Film) — Archival Records, Silver-Gelatin Type, on Cellulose Ester Base.*

Introduction

The Image Stability Test was devised by ANSI to judge the stability of photographic films on polyester and cellulose triacetate bases. Photographic paper samples will also be included in this experiment although they are not covered by the standard. The standard sets out criteria for judging whether density changes induced in radiometric and microfilm materials constitute passing or failing the stability test. According to this standard, however, other photographic materials are considered stable when "the image shows no sign of degradation which would impair the film for its intended use, when tested as described." A special ANSI task group is currently attempting to establish a more quantitative measure of image degradation for other films including those used for pictorial photography.

We discussed in Chapters 3 and 9 the role that humidity and temperature play in determining the stability of photographic materials: elevated temperature and humidity accelerate deterioration based on chemical reactions. The stability test accelerates the rate of any chemical reactions that may be occurring with the image-forming substance. The samples are subjected to elevated temperature and relative humidity for a period of 30 days.

In these experiments a sealed glass desiccator jar is used at high temperatures. Consequently, added emphasis must be placed on wearing protective safety equipment. Safety goggles for eye protection must be worn. Special gloves for handling hot equipment must be worn when handling the heated desiccators and the appropriate gloves must be worn when mixing the saturated salt solution. It may also be required that the desiccator be taped to limit damage from flying debris should breakage, implosion or explosion occur. Lab coats must be worn at all times.

Materials and Apparatus

- 4 step tablets imaged on polyester-base film
- 4 step tablets imaged on cellulose triacetate film
- 4 grey scales imaged on fibre-base paper
- 4 grey scales imaged on resin-coated paper (refer to Chapter 4 for the above)
- saturated salt solution: sodium nitrate
- glass jar desiccator
  - 9-liter size
  - 250-mm diameter
- sample hanger
- high vacuum grease
- aging oven
- reflection densitometer
- transmission densitometer
- prepared Kodak Curve Plotting Graph Paper
- hole punch

Procedure

1. Turn on the aging oven. Set the thermostat at 60°C.

2. Prepare a saturated solution of sodium nitrate ($NaNO_3$) at 60°C so that the solution contains an excess of undissolved crystals (see Section 2.6.1). This will maintain a relative humidity of 67.5% at 60°C in the desiccator.

3. Place the salt solution in a shallow dish. The excess crystals must be completely covered by the saturated solution. Set the dish in the bottom of the desiccator. Grease the desiccator lid seal if necessary, replace the lid, check the seal, and close the stopcock. Place the desiccator in the oven for conditioning for 20 hours prior to the introduction of the samples.

4. Assemble the required samples, as listed above. Samples should be no longer than 12.5 cm and no wider than 2.5 cm. Measure and record visual and tricolor density readings of every step of each sample.

5. Take one of each of the different sample types and set them aside in sleeves as controls for visual comparison with the incubated samples. Control samples are to be kept at room temperature and relative humidity not greater than 60%.

6. Punch a small hole in the top border of each sample so that it can be hung from the desiccator sample holder. Place the samples on the hanger. They should hang free without touching the other samples.

7. When the samples are hung and the desiccator conditioned, remove the desiccator from the oven, open the stopcock, remove the lid, place the hanger inside, replace the lid, and close the stopcock. Return the desiccator to the oven for 30 days.

8. The oven temperature should be checked daily. A temperature of 60°C ± 2°C must be maintained. At the same time, one should check to be sure that the lid seal remains tight and that the saturated salt solution hasn't evaporated.

9. After 30 days, remove the desiccator from the oven, open the stopcock, and slide off the desiccator lid. Remove the samples and let them cool before taking density readings.

10. Take and record visual and tricolor density readings of all steps on each incubated sample.

11. Average the visual density readings of samples of the same type before incubation and after incubation. Draw the before and after characteristic curves for each sample type on the same piece of calibrated graph paper.

12. Using the control samples, make visual and densitometric comparisons of incubated and non-incubated samples.

Analysis

Write a brief report on the relative stability of the four materials tested above, illustrated by density readings, characteristic curves, and samples.

Question

1. What quantitative standards can you suggest to determine when a pictorial film passes or fails this test?

10.1.3 Experiment 2: Black-and-White Light Fading Test

Purpose

To perform the ANSI Test for Stability to Light, as outlined in PH4.32-1986, *Methods for Evaluating Processing with Respect to the Stability of the Resultant Image — Black-and-White papers*, Section 5.2.

Introduction

Black-and-white silver gelatin photographic materials that have been properly processed and stored in controlled environments exhibit a high degree of light stability. The baryta layer, which is essentially inert, protects the cellulose fibres of print materials from display illumination. In resin-coated papers, however, the polyethylene layer is pigmented with titanium dioxide (TiO_2), which is subject to photolytic degradation and can produce oxidizing agents that lead to cracking of the polyethylene layer. The cracking problem appears to have been solved by the addition of stabilizers.

Ultra-violet radiation, which is more energetic than visible light, is found primarily in fluorescent lighting and sunlight. For this reason, this experiment will subject test samples of contemporary grey scales to ultra-violet radiation and visible light. (Unlike tungsten light, fluorescent light does not generate high temperature levels.) The test will take place under normal room temperatures and humidity conditions (24°C ± 3°C and 45% RH ± 5%). The samples will be subjected to relatively high-intensity illumination for various times. The illumination level will be 500 footcandles, which is greater than normal for most display and exhibit areas.

Materials and Apparatus

- 4 paper samples: 4" × 5" fibre-base (Ilford Ilfobrom Galerie, refer to Experiment 15: 4.5.1)
- 4 paper samples: 4" × 5" resin-coated (Ilford Ilfospeed, refer to Section 2.3.2)
- 4 film samples: 4" × 5" polyester-base film
- 4 film samples: 4" × 5" cellulose triacetate-base film
- film and paper processing chemicals
- Hope 152 Black-and-White Film Processor
- 4 fluorescent light sockets
- 4 fluorescent "deluxe cool white" bulbs
- footcandle meter
- ultra-violet light monitor
- Kodak storage envelopes
- transmission densitometer
- reflection densitometer
- exposure template from Experiment 1: 4.2.1
- sensitometer

Procedure

1. Prepare film samples: Expose four sheets of polyester-base film in the sensitometer, using the exposure template from Experiment 1: 4.2.1. The correct exposure will produce at least one and no more than two steps equal in density to the "base plus fog" of the sample. Label the samples. Process them in the Hope 152 Black-and-White Film Processor at 50% base speed. Put the processed samples through another fixing bath, rinse, hypo clearing bath, and wash.

2. Repeat this procedure with the four sheets of cellulose triacetate-base film.

3. Prepare and archivally process the four fibre-base and four resin-coated paper samples (see Chapters 2 and 4). Label samples.

4. If disassembled, reconstruct the testing light source. Mount the four fluorescent light fixtures side by side on a piece of 1/4" plywood, which has been cut to a slightly larger length than the fixtures. Cover this panel with tin foil, shiny side out. Stand the fixtures vertically against a wall. Fasten the plywood securely to the wall. Insert the tubes in the light fixtures.

5. Reconstruct if necessary the free-standing base that will be parallel to the light board.

The base must be movable, so that the correct intensity can be achieved by increasing or decreasing the distance from the light source.

6. Determine the correct position of the free-standing base to achieve an illumination of 500 footcandles. Using the ultra-violet monitor, determine the level of ultra-violet radiation. Be sure the illumination is even across the entire panel.

7. Take visual and tricolor density readings of every step of each grey scale and step tablet of the sample groups. Record these values.

8. Mark each one of the four samples in each of the two film and paper groups according to the following division:

Samples A	15 days
Samples B	30 days
Samples C	45 days
Samples D	control group

Place the four control samples (one from both films and both paper types) in light-tight Kodak storage envelopes.

9. Pin the remaining 12 samples (four each in A, B, and C) to the movable panel, using stainless steel pins.

10. Turn on the lights, and keep them on for the duration of the test (45 days).

11. After 15 days, remove Samples A.

12. After 30 days, remove Samples B.

13. After 45 days, remove Samples C.

14. Read and record visual and tricolor density readings for each step of all the grey scales and step tablets for all samples that were exposed to light testing. Draw before and after curves for each material type and fading condition.

15. Determine the total number of footcandle hours to which each sample group was subjected.

Analysis

Write a brief report on the results, comparing the control samples and the tested samples.

Questions

1. If the level of illumination at an exhibit is 100 lux for eight hours, what length of exhibition time do these tests represent (in days, months, or years)?

2. What recommendations can you make on the basis of these test results?

10.1.4 Experiment 3: Gas Fading Test

Purpose

To perform peroxide and sulfide gas fading tests on contemporary black-and-white film and paper samples.

Introduction

There are many chemical elements present in the air, and in poor quality filing enclosures, which will chemically react with image silver. The primary agents of destruction are sulfides and peroxides. The relative vulnerability of a contemporary photograph to a contaminated atmosphere or immediate storage environment can be determined by exposing sample photographs to sulfur compounds or peroxides.

The use of toning baths has long been known to protect silver images by converting some or all of the image silver to a more stable compound. Of particular interest is the stabilizing effect of selenium toning. At relatively low dilutions (1:19 toner to water, toning baths), this toner dramatically increases the stability of image silver while changing the image tone very little. In this present experiment, both toned and untoned paper and film samples that have been processed for permanence will be placed in peroxide and sulfide atmospheres. Changes due to the test will be evaluated by visual examination and by visual and tricolor density readings.

In this experiment, poisonous substances are used to produce oxidizing gases. These materials must be used only in the fumehood. Safety goggles for eye protection and neoprene gloves must be worn, as well as the usual lab coat.

Materials and Apparatus

- *Film*:

  8 untoned step tablet samples (1" × 5", 21 steps) from Experiment 15: 4.5.1

  8 selenium-toned (1:19) film samples from Experiment 15: 4.5.1

- *Paper*:

  8 untoned grey scale samples (1" × 5", 21 steps) from Experiment 15: 4.5.1

  8 selenium-toned (1:19) paper samples from Experiment 15: 4.5.1

- 2 large desiccators
- saturated salt solution to maintain 80% RH
- neutral peroxide solution: 30% H_2O_2
- sulfide solution: 0.1% Na_2S/HCl
- transmission densitometer
- reflection densitometer
- prepared Kodak Curve Plotting Graph Paper
- sample hangers
- hole punch
- HB pencil

Procedure

1. Film samples: 16 samples are required, 8 untoned and 8 toned with selenium toner (1:19). Take and record tricolor and visual density readings on the transmission densitometer. Mark samples using tiny notches cut into the border. Divide the samples into four groups, and label them.

   1. untoned — peroxide treated
   2. untoned — sulfide treated
   3. toned — peroxide treated
   4. toned — sulfide treated

2. Take one sample from each group and set them aside in a storage envelope. Store them at room temperature, RH not to exceed 60%. There remain six film samples to be treated in the peroxide atmosphere and six to be treated in the sulfide atmosphere.

3. Repeat steps 1 and 2 with the paper samples. The samples can be marked by using a soft HB pencil on the back. Use the same group divisions as listed in step 1 above. Take one sample from each group to serve as controls, and store them with the film samples.

4. Punch small holes in the top borders of each sample so they can be hung from the desiccator sample hangers. Hang group one and group three samples (toned and untoned film and paper) on one hanger, for the peroxide atmosphere. Hang group two and group four samples (toned and untoned film and paper) on one hanger, for the sulfide atmosphere. Be sure all samples are hanging freely, without touching the other samples.

5. Prepare the desiccators. Mix a saturated solution of $(NH_4)_2SO_4$ at room temperature. This solution will maintain an RH of approximately 80%. Using a small flat dish, place the salt solution in the bottom of the desiccator. Put the lid on the desiccator and seal it. This will condition the desiccator.

6. Once the desiccators are conditioned (about 20 hours), prepare the peroxide atmosphere. Open the stopcock and remove the lid of the desiccator. Under the fumehood, pour laboratory grade H_2O_2 (30%) into a shallow dish and set it into the bottom of the desiccator. Place the sample hanger containing groups one and three into the desiccator. Seal the lid and close the stop-cock.

7. Under the fumehood, mix up a 0.1% solution of sodium sulfide in hydrochloric acid, to make 200 mL of solution using the following formula:

Distilled water	170 mL
Na_2S	0.2 gram
HCl [37%]	0.6 mL
Distilled water to make	200 mL

Place this in a shallow dish and set it in the bottom of the second desiccator. Place the second sample hanger containing sample groups two and four into the desiccator. Seal the lid and close the stopcock.

8. The duration of the test is seven days, after which the stopcock of the dessicator is opened, the lid removed, and the samples removed. (Open the desiccators under the fumehood.) Remove the samples from the hanger and let them air out for two hours before removing them from the fumehood and handling them with bare hands. Take visual and tricolor density readings of each step of each sample.
9. Make a visual examination of every sample and compare each to the corresponding control sample.

Analysis

Write a brief report on the results, as determined by an analysis of both density readings and visual examination.

Questions

1. What are the relative shortcomings of a test like this?
2. What variables are left uncontrolled or unaccounted for?

10.1.5 Experiment 4: Color Image Stability Test

Purpose

To perform the ANSI Color Image Stability Test, as outlined in ANSI PH1.42-1969, *Methods for Comparing the Color Stabilities of Photographs*, Section 3.7.

Introduction

The dyes used in most contemporary color photographic materials are known to be unstable. They fade both in the presence of ultra-violet radiation and at a slower rate in tungsten light. Even when kept in the dark, color dyes will fade with time. This latter phenomenon, called "dark fading," is generally accelerated by increased temperatures and high humidities. The ANSI Temperature and Relative Humidity Test determines the extent of dark fading in the presence of various temperatures and relative humidity levels and is divided into three conditions. The first simulates tropical conditions: 37.7°C ± 0.6°C (100°F ± 1°F) and 90% ± 2% relative humidity. The second simulates results that occur with long-term storage: 60°C ± 0.6°C (140°F ± 1°F) and 70% ± 2% relative humidity. The third tests for fading that is caused primarily by heat: 76.6°C ± 0.6°C (170°F ± 1°F) with less than 5% RH. The samples to be used (Kodak Color Control Strips for Kodak Ektacolor Plus Paper, Process EP-2; and Kodak Control Strips, Process E-6) contain patches of the individual dye layers, along with patches of black-and-white. The white patch will indicate a staining of non-image-silver areas; the black patch will reveal any mottling or density unevenness that may occur. This experiment will deviate from the ANSI standard in that saturated salt solutions or molecular sieves will be used to maintain the correct humidities. The standard calls for the use of forced-air recirculating chambers to maintain the correct temperatures and humidities.

In this experiment sealed glass desiccator jars are used at high temperatures. Consequently, added emphasis must be placed on wearing protective safety equipment. Safety goggles for eye protection must be worn. Special gloves for handling hot equipment must be worn when handling the heated desiccators and the appropriate gloves must be worn when mixing the saturated salt solutions. It may also be required that the desiccator be taped to limit damage from flying debris should breakage, implosion, or explosion occur. Lab coats must be worn at all times.

Materials and Apparatus

- color print samples:
  21 Kodak Color Control Strips, Process EP-2
- color transparency samples:
  21 Kodak Color Control Strips, Process E-6 (35-mm × 100 ft roll)
- transmission densitometer
- reflection densitometer
- Enterprise Photo Processor for E-6 processing
- 3 glass desiccator jars
- 3 aging ovens
- KNO_3 and $NaNO_3$ to make saturated salt solutions
- 4 Angstrom type molecular sieves grade 513 4 - 8 mesh

Procedure

1. Process 21 E-6 Color Control Strips in the Enterprise processor. Send 21 EP-2 Color Control Strips to a processing lab to receive standard Ektaprint processing.

2. Divide both sets of samples into seven groups of three samples each, to receive the following treatments:

   Group A1 7 days (Condition A)
   37.7°C ± 0.6°C (100°F ± 1°F) 90% ± 2% RH

   Group A2 14 days (Condition A)
   37.7°C ± 0.6°C (100°F ± 1°F) 90% ± 2% RH

   Group B1 7 days (Condition B)
   60°C ± 0.6°C (140°F ± 1°F) 70% ± 2% RH

   Group B2 14 days (Condition B)
   60°C ± 0.6°C (140°F ± 1°F) 70% ± 2% RH

   Group C1 2 days (Condition C)
   76.6°C ± 0.6° C (170°F ± 1°F) < 5% RH

   Group C2 7 days (Condition C)
   76.6°C ± 0.6° C (170°F ± 1°F) < 5% RH

   Group D 14 days (Control)
   Frozen

3. Label each sample carefully, using notches or pencil notations.

4. Take visual and tricolor density readings of all color and black-and-white patches on each of the test samples. Record values in chart form.

5. Take the three samples from group D (six samples in all) and place them in Kodak storage envelopes, one per envelope. Label each envelope. Squeeze out all the air and seal the end so that it is airtight. Place the controls in the envelopes in the freezer. Leave them there for the duration of the test.

6. Prepare the saturated salt solutions and place them in shallow dishes in the bottom of the desiccators.

   90% RH: use KNO_3 saturated solution
   70% RH: use $NaNO_3$ saturated solution
   5% RH: use 500 grams of molecular sieves

7. Condition the desiccators for 20 hours prior to putting in the samples as performed in Experiment 1: 10.1.2.

8. Place the samples on the sample hangers, six E-6 and six EP-2 strips per hanger. Place the sample hangers in the desiccators. Place the desiccators in the oven for the following initial times:

Condition A:	7 days
Condition B:	7 days
Condition C:	2 days

9. After two days, remove three EP-2 and three E-6 samples from the Condition C desiccator. Read and record all density values of these samples, as in step 4 above. The remaining Condition C samples are returned to the desiccator and the oven for the remaining five days.

10. After a total of seven days, remove the remaining samples from the Condition C desiccator. Remove the six samples from each of the A and B desiccators (three EP-2 and three E-6). Return the remaining samples in the Condition A and B desiccators to their ovens.

11. Read and record all the densities from the samples removed after seven days, as in step 4 above.

12. After a total of 14 days, remove all remaining samples from the ovens and read and record all density values.

13. Remove all the control strips from the freezer. Let them warm up for four hours before removing them from their envelopes.

14. Read and record all density values for all the control strips.

Analysis

Write a brief report on your findings using the density readings and including visual examinations.

Question

1. Can you draw any conclusions regarding the stability of one dye over another?

10.1.6 Experiment 5: Color Light Fading Test

Purpose

To perform light fading tests on a contemporary color print material and a color transparency material.

Introduction

The light fading characteristics of contemporary color print and transparency materials are well documented by both industry and independent researchers. Light fading is, in fact, a combination of light and dark fading, as the mechanism for dark fading is still in place during exposure to light.

Ultra-violet radiation is destructive to cellulose and other components of photographs, including color dyes. (See Chapter 9.) Black-and-white materials are relatively stable in light, and particularly in tungsten light, which lacks ultra-violet radiation. Color materials, however, have been determined to be unstable under tungsten illumination as well as ultra-violet radiation. This creates serious problems for curators, as well as for the average person trying to preserve family portraits. This experiment will test contemporary print and transparency samples under fluorescent and tungsten illumination.

Materials and Apparatus

- print samples:
  21 Kodak Color Control Strips, Process EP-2
- transparency samples:
  21 Kodak Color Control Strips, Process E-6
  (35-mm × 100 ft roll)
- transmission densitometer
- reflection densitometer
- fluorescent light source from Experiment 2: 10.1.3
- tungsten light source: 4 sockets, 4 500-watt bulbs,
  heat-absorbing glass
- fan
- Enterprise Photo Processor E-6 for processing
  (refer to operator's manual)

Procedure

1. Send 21 EP-2 Color Control Strips to a photo finishing lab for Ektaprint processing.

2. Process 21 E-6 Color Control Strips in the Enterprise processor.

3. Take visual density readings of all color and black-and-white patches on each of the samples. Record the values and label all samples.

4. Divide both the film and paper samples into seven groups of three samples each, according to the length and type of exposure:

   Group 1: 5 days of exposure to tungsten light

   Group 2: 15 days of exposure to tungsten light

   Group 3: 30 days of exposure to tungsten light

   Group 4: 5 days of exposure to fluorescent light

   Group 5: 15 days of exposure to fluorescent light

   Group 6: 30 days of exposure to fluorescent light

   Group 7: Control — Dark storage and room temperature

5. Label each sample. Take the three control samples of each material type, place them in light-tight envelopes, squeeze the air out of the envelopes, and seal them. Store envelopes at ambient room temperature and relative humidity.

6. Set up the fluorescent light source as outlined in Experiment 2: 10.1.3. Pin to the movable panel the three samples from each group four, five, and six of the two film and paper types (a total of 18 samples). Set the panel at a point where it will receive 500 footcandles of illumination.

7. If necessary, reassemble the tungsten light source. Group four standard light sockets on a piece of plywood. Cover the panel with aluminum foil shiny side out. Place four 500-watt bulbs into the sockets. Fasten this light panel securely to a wall. If necessary, reconstruct a free-standing panel on to which samples can be pinned. Between this panel and the light source, place a piece of heat-absorbing glass. Place a fan to the side to blow gently across the heat-absorbing glass and samples, to prevent excessive heat build-up. Place the panel so that the samples receive an illuminance of 500 footcandles.

8. Pin the remaining samples to this movable panel (nine EP-2 and nine E-6, to total 18 samples).

9. Turn on both light sources and let the samples sit under continuous illumination for five days.

10. After five days, remove groups one and four and record the sample densities as in step 3.

11. After 15 days, remove groups two and five and record the sample densities as in step 3.

12. After 30 days, remove groups three and six and record the sample densities as in step 3.

13. Take density readings at all areas read in step 3, from the samples kept in the dark. Make a visual comparison of all the samples.

Analysis

Write a brief report of your findings.

Questions

1. From your findings, can you calculate approximately how long these samples could have been displayed at 100 lux, eight hours per day, before slight and profound changes in color densities would have occurred?
2. Why is there a need to control the heat from the tungsten illumination source?

10.2 Tests for Determining the Response of Photographs to Treatments

10.2.1 Photographic Materials Testing: Introduction

The four experiments in this section deal with testing the physical properties of the gelatin emulsion. During processing and any subsequent treatments, the gelatin emulsion is subjected to a variety of stresses. Immersion time in aqueous solutions, the temperature and pH of processing solutions, and the use of hardening baths all affect the degree of swelling of the gelatin layer and may affect its stability when later dried. Because we often do not know the origin of a silver-gelatin photograph or how it was processed, often years before a conservator or conservation researcher sees it, some of these tests give us the means to determine the relative stability of these materials. The tests in this chapter are often destructive or potentially destructive. They are designed more as research tools than as tests appropriate for the evaluation of historical photographs with any value.

Support layers, including paper, polyester, and cellulose triacetate, are not included in this testing. Their properties are well known through the published research carried out in the photographic industry, studies that are far more detailed and in depth than would be possible in the Photograph Conservation Laboratory.

The physical properties of gelatin are not under scrutiny here, but rather the physical response of photographic emulsions during and after processing and conservation treatments.

10.2.2 Experiment 6: Melting Point Test

Purpose

To perform the melting point test on a variety of contemporary film samples as described in ANSI PH4.11-1981, *Determining the Melting Point of a Non-support Layer of Films, Plates, and Papers.*

Introduction

ANSI defines "melting point" as "the temperature at which the first visible evidence of a change in physical structure of a photographic emulsion or other non-support layer is observed in a rising-temperature melting point bath, as specified in this standard." ANSI provides two reasons for conducting these tests, both of them relevant to the concerns of photograph conservators:

1. To serve as an indication of the inherent resistance of the (gelatin) layer to disintegration in solution at elevated temperatures.
2. To observe the tanning or hardening action imparted by processing solutions through which it has passed.

The melting point test is not designed to determine the melting point with the same precision as conventional chemical melting point tests. Nor does it establish maximum safe temperatures for processing solutions. Because of the many variables inherent in tests involving photographic emulsions, such as the effect of immersion time, the accuracy rate is ± 4°C. A salt solution is used, rather than distilled water, as it more nearly corresponds in its effects to the effect of some processing solutions on the non-support layer.

Materials and Apparatus

- *Film samples:* (Kodak Plus-X Pan Professional Film)
  4 sheets, 8 × 50 mm, 1/2 D-max /1/2D-min,
  fixed in hardening fixer
  4 sheets, 8 × 50 mm, 1/2 D-max/1/2 D-min,
  fixed in rapid non-hardening fixer
- *Paper samples*: (Ilford Ilfobrom Galerie Paper)
  4 sheets, 8 × 50 mm, 1/2 D-max /1/2 D-min,
  fixed in hardening fixer
  4 sheets, 8 × 50 mm, 1/2 D-max /1/2 D-min,
  fixed in rapid non-hardening fixer
- thermometer
- enlarger
- film holders
- test tube rack with hangers
- 4-liter beaker
- stirrer
- test tubes with lips:
  13 mm outside diameter × 100 mm length
- stainless steel clips to suspend samples in test tubes
- large hot plate
- melting point solution:
  distilled water
  sodium carbonate (anhydrous)
  sodium sulfite (anhydrous)
- film processing chemicals:
  including hardening and non-hardening fixers
- paper processing chemicals:
  including hardening and non-hardening fixers

Procedure

1. Produce film samples. Place two sheets of film in film holders. In complete darkness, place them under the enlarger. Open the holder slide half way. Expose the sample to light long enough to get a solid D-max area. Tray process the film in Kodak HC-110 (dilution B) for the recommended time. Fix in Ilford Ilfospeed rapid fix for 30 seconds and

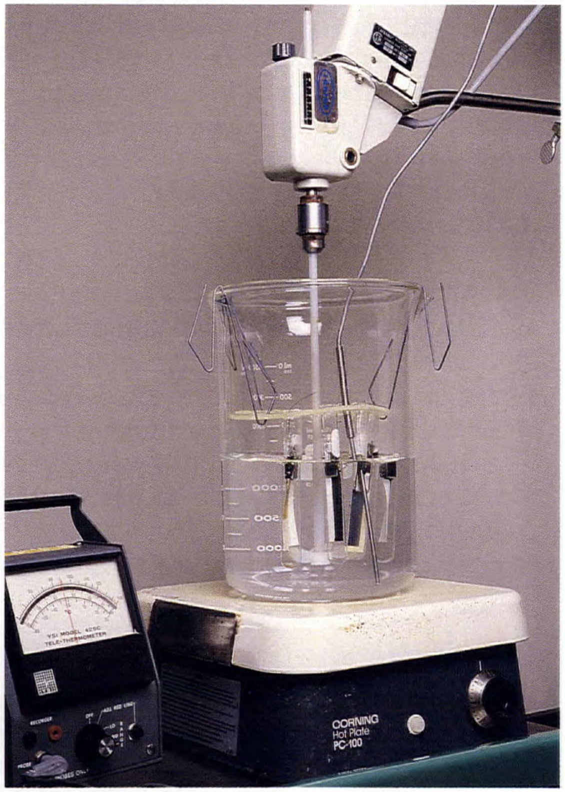


Fig. 10.1: Melting point test apparatus.

rinse for 1 minute. Place in a hypo clearing bath for 2 minutes, wash thoroughly for 20 minutes, and dry.

2. Repeat step 1, using Kodak fixer (a hardening fixer) and the manufacturer's recommended processing times for fixing, hypo clearing, and washing.

3. Produce paper samples. Cut an 8" × 10" sheet of photographic paper in half; return half to the paper safe. Place the half sheet in the paper easel. Cover half of the sheet with an opaque material. Expose the sheet long enough to get a dense black (D-max). The covered half should remain completely unexposed. Process the paper in Dektol (1:2), stop bath, and rapid non-hardening fixer (such as Ilford Ilfospeed Fix). Rinse, place in a hypo clearing bath, and wash thoroughly. Completely dry the paper samples. (Refer to Chapter 4 for processing details.)

4. Repeat step 3, using Kodak fixer for five minutes.

5. Cut four samples from each film and paper sheet to the required size of 8 mm × 50 mm with half the sample area D-max and half D-min. Label all film and paper samples.

6. Divide the samples into two groups, according to the type of fixer used:

Group 1	non-hardening fixer	4 film samples 4 paper samples
Group 2	hardening fixer	4 film samples 4 paper samples

7. Remove one film and one paper sample from each group. Set them aside to serve as pre-test controls. This leaves six samples in each group.

8. Mix the melting point solution according to the following formula, to make 1 liter of solution:

Distilled water	900 mL
Sodium carbonate (anhydrous)	25 grams
Sodium sulfite (anhydrous)	50 grams
Distilled water to make	1 liter

9. Set up the equipment as illustrated in Figure 10.1. Using small clips, suspend the six group one samples in dry test tubes, one sample per tube, so that they are all at the same level within the tube. Place the test tubes in the circular rack and hang the rack in the beaker.

10. Repeat step 9 with the group two samples in a second circular rack.

11. Heat the melting point solution to 25°C and maintain it at this temperature. Both the melting point solution in the beakers and in the test tubes must be at this temperature before testing begins.

12. Turn on the hot plate to its maximum setting.

13. When the hot plate reaches its maximum temperature, fill the beaker with the melting point solution to the indicated level. The level marker marks the volume of fluid that the hot plate will be capable of heating at the correct rate.

14. Rapidly fill the test tubes with melting point solution to within approximately 1 cm of the top of each tube. Once the tubes are full, lower the rack into the beaker. Adjust the liquid levels, if necessary, to be sure the level of fluid in the beaker matches the level inside the tubes.

15. Insert a thermometer into the circular ring and place the beaker with ring and samples onto the hot plate. Place the motorized stirrer in the beaker and turn it on. A clear view of all samples and thermometer is essential, so that the exact time and temperature at which deterioration occurs can be recorded. It may be necessary to adjust the angle of the test tubes and thermometer for optimum viewing by rotating them in the ring.

16. The ANSI test specifies the amount of time the melting point solution should take to go from 25°C to boiling: 3.3°C per minute, or 23 minutes total time ± 2 minutes. The experiment must be timed to check how long it has taken, and the total time from placing the beaker on the hot plate to boiling must be noted.

17. The melting point is defined in the introduction above. Ignore lifting or flaking of the emulsion within 1.5 mm of the sample edge. If damage occurs for any sample before the solution boils, record the temperature at

which the first damage was noted. If damage occurs after the solution has boiled, record the time since the solution began to boil and the temperature. If any samples remain intact for more than 10 minutes of boiling, stop the experiment and report the results for each intact sample as "intact after 10 minutes boiling at _____°C."

18. Turn off the heat, remove the beaker using heat-proof gloves and allow the melting point solution to cool to 25°C. Repeat steps 12 through 17 with the group two samples.

Analysis

Write a brief report on the results of this experiment.

Questions

1. What is the difference between the melting points of the D-max and D-min areas?
2. Why aren't the samples suspended directly in the beaker solution?

10.2.3 Experiment 7: Swelling Test

Purpose

To carry out swellmeter tests on historical and contemporary black-and-white paper samples.

Introduction

Gelatin emulsions swell when placed in aqueous solutions as they take up water. The rate and degree of swelling is dependent on the composition of the emulsion as well as the temperature, pH, and composition of the solution. Contemporary emulsions are quite stable under the processing conditions they were designed for. However, if left in aqueous solutions for extended periods of time, most emulsions will absorb water continuously until the gelatin breaks up. This is not likely to occur during normal processing even when the manufacturer's wash times are somewhat extended but is more a danger for photographs stored in areas that may be flooded by natural causes or during the course of extinguishing a fire. Similarly, older photographs that have faded or require some form of chemical restoration or restoration technique that uses water may break up readily when immersed in aqueous solutions. Certain storage conditions may have adversely affected the stability of the gelatin. In addition, some treatments may be too harsh for gelatin emulsions, dissolving even contemporary samples. Extended immersion times and drastic pH changes can cause the emulsion to separate from the base or swell until it breaks apart.

Monitoring the degree of emulsion swelling may be done before, during, and after treatment with the use of a swellmeter (Green, 1972). The swellmeter has a probe on a variable speed timer, which takes readings of the thickness of a film or paper sample. The samples are positioned when dry.

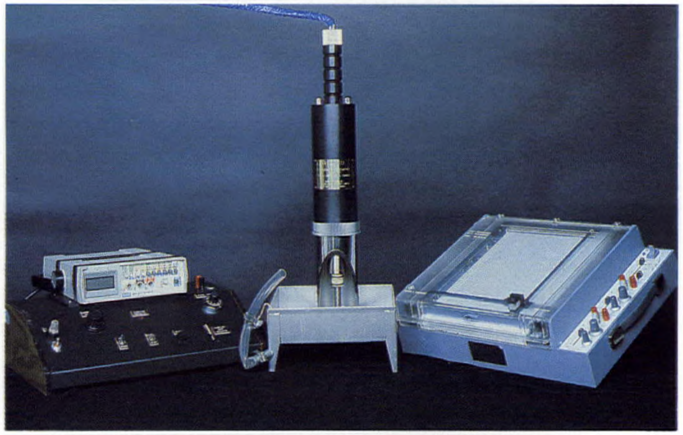


Fig. 10.2: Swellmeter.

(The entire machine must be dry so that no swelling occurs prior to the introduction of the desired testing solution.) The reading is plotted on graph paper and is accurate down to approximately one micrometer. The graph first exhibits a drastic, rapid change in thickness, which includes swelling of the paper support layer in prints and the anti-curl backing layer on films. The effect on the gelatin layer is monitored as the sample goes from one solution to the next.

In this experiment, contemporary and historical photographic materials will be subjected to normal black-and-white processing solutions in order to gain familiarity with the device and as a way of demonstrating the different effects of the solutions on a range of photographic materials. More elaborate testing using the swellmeter in this laboratory has determined the advisability of using hardening baths to de-swell the gelatin at crucial points in bleach and redevelopment procedures.

Materials and Apparatus

- 2 samples Ilford Ilfobrom Galerie paper
- 2 samples Kodak Azo (single weight) paper
- 2 discarded historical silver gelatin prints
- Ilford Galerie processing chemicals
  800 mL of each
- acetic acid stop bath 800 mL
- 1600 mL of each of the following:
  Kodak Dektol developer
  Kodak Indicator Stop Bath
  Kodak fixer
- Kodak Hypo Clearing Agent
- swellmeter
- mechanical stirrer

Procedure

1. Prepare the required processing solutions.

2. Prepare the paper samples. Small samples (2" × 2") should be cut from sheets of unprocessed paper. Cut the discarded vintage photograph into 2" × 2" pieces.

3. Carry out the remaining steps only after having read the Green and Levenson article (Green, 1972).

4. Set up the equipment for the experiment and turn on the power.

5. Place the first sample in the sample holder on the probe base emulsion side up. Samples can be exposed to light during the entire procedure. Position the motorized stirrer. Turn on the probe.

6. Process the Ilford Ilfobrom Galerie samples first. Pour in 800 mL of the Ilford PQ developer. Turn on the stirrer and develop the sample for two minutes.

7. Drain the tray and pour in the stop bath, with the probe and stirrer continuing to operate. Drain after 30 seconds.

8. Pour in the Ilford Ilfospeed Fixer with the probe and stirrer operating. After 30 seconds, drain the tray. Place a hose in the tray with running wash water. The water entering the tray should do so at a slow rate, so as not to dislodge or move the paper sample. Wash for five minutes with the probe running.

9. After five minutes drain the water. Add Ilford Galerie Washaid and treat for 10 minutes with the stirrer and probe operating.

10. After 10 minutes, drain the tray and wash again for another 5 minutes, using the same washing procedure as in step 8.

11. Turn off the probe and stirrer. Remove the sample after five minutes of washing. Squeegee the sample and air dry it.

12. Dry the probe and sample holder with a hot air gun held at a distance to control the heat.

13. Place the Kodak Azo paper sample in the holder. Turn on the probe and stirrer. Pour in the Kodak Dektol developer. Develop for 1 $^1/_2$ minutes. Drain the developer.

14. Follow the remaining processing steps, draining between steps and operating the probe and stirrer continuously, as outlined above.

    Kodak Indicator Stop bath, 30 seconds
    Kodak fixer, 5 minutes
    Water rinse, 1 minute
    Kodak Hypo Clearing Agent, 3 minutes
    Wash, 20 minutes

15. Drain the last tray, remove the sample, squeegee it, and air dry.

16. Repeat steps 12 through 15, using the historical print sample.

17. Examine the plotted results, comparing the responses of all three samples to the various processing steps.

Analysis

Write a brief report comparing the responses of the three samples.

Question

1. What accounts for variations in response to the two different fixing baths?

10.2.4 Experiment 8: Scratch Resistance Test

Purpose

To carry out scratch resistance tests on a contemporary black-and-white photographic film, according to the procedure outlined in ANSI PH1.37-1977, *Methods for Determining the Scratch Resistance of Processed Photographic Film.*

Introduction

Photographic films must have sufficient scratch resistance to be handled by machines such as cameras and projectors and to be usable under normal handling conditions both before and after processing. Various treatments are available to enhance an emulsion's resistance to scratching. This ANSI test offers one way to judge the scratch resistance of various films and the effectiveness of treatments designed to enhance their scratch resistance.

Films react differently to different scratching mechanisms. Under some conditions, e.g., free rolling grit particle abrasion, a particular film may be more resistant than others. The same film may react poorly to abrasion caused by being moved over a stationary sharp object. Therefore, there is no absolute measure of scratch resistance. This test provides only a reasonable indication of a film's ability to resist scratches under normal handling. Reliable measurements using this test depend on three conditions. High relative humidity will affect the degree of swelling and the hardness of the gelatin. Comparative tests must therefore be carried out under consistent RH levels. Processing should be standard throughout the tests. Surface friction is affected by the lubrication contributed by fingerprints and lacquers. Care must be taken to keep samples clean.

ANSI PH1.37-1977 provides two methods, A and B, which yield similar information. Method B is more complete and is the preferred test. In this experiment Method A will be used. We will also deviate from the standard in our method of evaluation. ANSI calls for a visual examination of the projected sample, mounted in a slide mount, viewed from 4 feet and 15 feet. The first visible scratch and the corresponding load weight on the stylus indicates the scratch resistance. In this experiment a stereomicroscope at 10 times magnification will be used in conjunction with a raking light source.

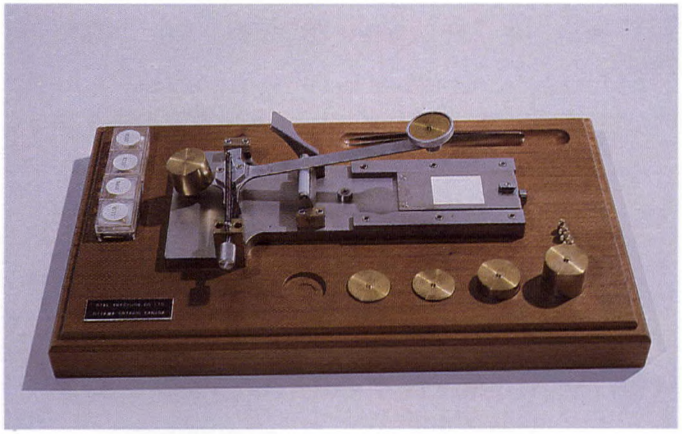


Fig. 10.3: Scratch resistance tester.

Materials and Apparatus

- 3 sheets Kodak Ektapan Film, 4" × 5"
- Hope 152 Black-and-White Film Processor
- Kodak SH-1 hardening bath
- Kodak Hypo Clearing Agent
- film washer
- Spherical Stylus Scratch Tester
- stereomicroscope

Procedure

1. Read ANSI PH1.37-1977.

2. It is essential that unprocessed and processed film samples be handled only while wearing white lintless gloves. Fingerprints can cause the stylus to skip or slide across the surface, invalidating results.

3. Prepare film samples. Samples with "no significant optical density" are called for. Do not expose the samples prior to processing. Run three sheets of Kodak Ektapan Film through the Hope 152 processor. Label the samples. Following processing, treat the samples in the following manner:

   Sample 1: Give no after treatment.

   Sample 2: Rinse in water.

   Hypo Clearing Bath: 2 minutes
   Wash: 10 minutes

   Sample 3: Rinse in water.

   Kodak SH-1 hardening bath: 3 minutes
   Hypo Clearing Bath: 2 minutes
   Wash: 10 minutes

4. From each processed and dried sheet of film, cut a sample 24 mm × 36 mm, so that the long side of the sample runs parallel to the length of the film sheet.

5. The samples should be exposed to the atmosphere in which the test will be carried out long enough to reach an equilibrium. Setting the samples out overnight will accomplish this. The recommended RH for this test is 50% ± 5%. This is an average RH value and should be reproducible for subsequent tests. Many modern air-conditioned buildings maintain a fairly stable RH level.

As long as it is reasonably low (between 40% and 60%), the test can be conducted. The required temperature is 21°C.

6. Examine the ANSI standard in order to become familiar with the apparatus and its operation.

7. Place a film sample in the sample holder emulsion side up. Position stylus laterally toward one side of the sample and toward the bottom edge, so that when the sample is scratched it is moving away from the pivot of the arm, or away from the center.

8. Place a 1-gram weight on the holder above the stylus. Slowly lower the stylus onto the film surface.

9. Pull the sample holder so that the stylus is dragged across the sample. The required speed is 0.5" to 2.0" per second.

10. Make two scratch lines for each weight, approximately 0.01" apart and at least 2 cm long.

11. Increase the load to 2 grams and draw two more lines, approximately 0.03" away from the first pair of scratches.

12. The recommended range of weight (in grams) is as follows:

1	2	4	6	8	10	15	20
30	40	50	60	70	80	90	100

Once the scratches become quite visible, it is not necessary to continue, and the test is terminated.

13. Evaluate the scratch resistance by comparing the loads required to scratch the emulsion. Place the samples under the microscope at 10 times magnification.

14. The significance of differences between ratings is as follows:

    a. Below a 10-gram load, a difference of a few grams is significant and reproducible.

    b. Between 10 and 40 grams, a 5-gram difference begins to be significant.

    c. Above 40 grams, a 10-gram difference is significant.

    "Significant" in these tests results refers to measurable differences, but implies nothing about practical applications.

15. Repeat the test. This time, cut 24 mm × 36 mm samples from the same sheets of film, taking the sample so that the long side of the sample runs parallel to the width of the sheet of film. This change of direction should affect the loads required to scratch the film.

Analysis

Write a brief report that compares the results of the six samples. Note any discernible differences resulting from different processing treatments and orientation of cut sample.

Questions

1. What correlation does there appear to be between hardened samples and non-hardened samples?

2. What would account for any difference in scratch resistance between length and width running samples?

3. Evaluation in this experiment is done differently than in Method A of the ANSI standard. What differences will this likely cause in comparison to results obtained by the ANSI method?

4. Do the scratches on the different samples appear to be different in any way? If so why?

10.2.5 Experiment 9: Wet Abrasion (Mushiness) Test

Purpose

To perform the wet abrasion test on contemporary film and paper samples, as outlined in ANSI PH4.35-1972, *Method for Determining the Resistance of Photographic Films to Abrasion During Processing.*

Introduction

Emulsions are more susceptible to abrasion when wet. The non-support layers of photographic films and papers are vulnerable to damage from sharp film corners, grit, fingernails, and tongs while in processing baths, and from rubbing against stationary parts of processing machines. The ability of photographs and negatives to resist damage from abrasion can be approximated by a wet abrasion test.

Each of the various processing methods, whether roller transport, tank line, or tray processing, poses potential problems. Abrasion test results must be interpreted in the context of the processing method used. Other factors affect wet abrasion resistance: the pH and temperature of processing solutions, the length of immersion time, the age and pre-processing storage conditions of the film or paper, and the inherent characteristics of the emulsion itself.

The mushiness tester, as this test device is often referred to, incorporates a tray where a sample may be placed in solution and scratched while wet. All

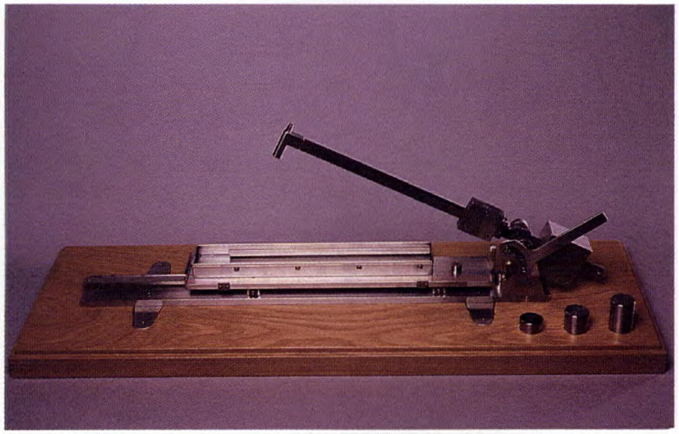


Fig. 10.4: Abrasion resistance tester.

preceding steps required for normal processing are to be completed in sequence immediately before the solution being tested. For example, if the effect of the fixing solution is being tested, develop the sample and place it in the stop bath. Then place it in the mushiness tester's tray emulsion side up and add the fixer. After the normal processing time in that solution, lower the stylus arm and begin testing.

This experiment will test the effect of hardening versus non-hardening fixers on the abrasion resistance of contemporary film and paper samples. The test can be used to evaluate processed samples by soaking them for 15 minutes in water.

Materials and Apparatus

- Kodak Plus-X Pan Film, 35-mm, 6 strips, 10" long
- Ilford Ilfobrom Galerie paper, 6 strips, 1 $^{3}/_{8}$" × 10"
- enlarger
- wet abrasion (mushiness) tester
- film processing solutions including hardening and non-hardening fixers
- paper processing solutions including hardening and non-hardening fixers
- 2 trays, 8" × 10"
- stereomicroscope

Procedure

1. Prepare film processing chemicals: HC-110 (dilution B), stop bath, two types of fixing baths (ANSI non-hardening and Kodak fixer). With the exception of fixer solutions, place solutions in trays.

2. *In the dark*, prepare the film samples by cutting off six 10" lengths of Plus-X Film from a bulk roll. Label samples. Place the strips in a light-tight box.

3. The film samples will be exposed very slightly under the enlarger so that a density is obtained between 0.5 and 1.0. Set up the enlarger with even illumination across the baseboard. Stop down the lens to approximately f/16. A good starting point for the exposure is five seconds. Expose sample one.

4. Process sample one for the following times:

   Develop: 4 1/2 minutes at room temperature, agitate 5 seconds every 30 seconds

   Stop bath: 10 seconds, constant agitation

5. Place sample one in the abrasion tester by sliding it into the sample tray. The tray should be placed as close in as possible towards the fulcrum of the arm. Pour in the non-hardening fixer and agitate gently for five minutes. After four minutes, turn on the room lights.

6. After five minutes, lower the stylus gently using the hand lever. Mark its location on the test strip. The carriage then should be pulled away from the fulcrum of the stylus arm, until it goes as far as it can. The travel time should be one to two seconds.

7. Lift the stylus, slide the tray back, and move the tray approximately 6 mm perpendicular to the direction of the scratch. Make a second marking notch, following the same procedure as in step 6.

8. If there is no indication of scratching, increase the number of grams on the sliding weight in 50-gram increments and repeat steps 6 and 7. A maximum of 150 grams can be added to the stylus arm.

9. Repeat the entire procedure outlined in steps 3 through 8, using samples two and three, one after the other. When these samples have been tested, replace the ANSI non-hardening fixer with Kodak fixer and test film samples four, five, and six.

10. *Under safelight illumination*, prepare the paper samples by cutting 8" × 10" sheets of Ilford Ilfobrom Galerie paper into six strips, 1 3/8" × 10" each. Label each sample. Place in a paper safe.

11. Prepare processing solutions as directed by the manufacturer for the paper samples: Ilford PQ developer (dilution 1:9), stop bath, fixers (ANSI non-hardening and Kodak fixer).

12. Samples will be exposed under the enlarger. Adjust the enlarger so that baseboard illumination is even. Stop down the lens to f/16 and expose the first sample for three to five seconds to get a midpoint or lower density.

13. Develop the paper sample for two minutes, place in a stop bath for 30 seconds. Immediately place the sample into the tray of the abrasion tester and fill it with ANSI non-hardening fixer. Fix for five minutes.

14. Follow the procedures in steps 6 through 8 above.

15. Repeat the paper testing procedures (steps 11 through 14), using samples two and three. Replace the non-hardening fixer with Kodak fixer and test paper samples four, five, and six.

16. Following the processing of all samples, rinse, place in a hypo clearing bath (two minutes for film, three minutes for paper), and wash thoroughly.

17. Evaluate the samples under the stereomicroscope at 10 times magnification. The wet abrasion resistance value is determined by measuring the distance that the stylus travelled before it dug into the emulsion or gelatin layer. Multiply the number of inches travelled by 10. Add any additional weights that may have been added during the experiment. This gives the mushiness values in grams. The measurement can be made while the sample is wet, or later, after it has dried. If the stylus skips, the distance to the first skip should be calculated, plus the distance to the beginning of a continuous scratch. Both results should be recorded.

18. When reporting results, the temperature of solutions, the type of lighting used to evaluate the scratches (reflected or transmission), the state of the sample at the time of evaluation (wet or dry), and any processing steps carried out after testing and before evaluation should be considered. The significance of the results can be gauged as follows:

    Low values (0-20 grams):
      a difference of 5 or 6 grams is significant

    High values:
      large numerical differences are required before being considered significant

Analysis

Write a brief report on the results, making a comparison between samples fixed in the hardening fixer and those fixed in a non-hardening bath.

Questions

1. Is there any correlation between the type of fixer and the abrasion resistance of samples? What accounts for this?

2. Is wet abrasion resistance a good indication of the hardness of the gelatin?

10.3 Tests for the Suitability of Materials Used in the Conservation of Photographs

10.3.1 Tests of Conservation Materials: Introduction

It is not difficult to find evidence in collections of damage caused to photographs by poor-quality mount boards, mats, envelopes and sleeves, and storage boxes. Contact with the wrong materials can cause considerable damage in the form of sulfiding of the image silver; the familiar silvering-out sheen, and disfiguring stains on all layers of photographic prints.

Many companies make what they advertise as "safe" or "archival" storage materials. It is often the conservator's job to validate these claims. All aspects of conservation materials and finished products must be considered by the conservator, whose job may well include the task of testing these materials to be sure they will cause no harm to the collections stored in them. The photograph conservator should consider any adhesive used and where it is placed on envelopes or sleeves; the kind of paper (e.g., the amount of lignin, and rag content); the colorings and inks used in or on the paper or product; the kind of plastic from which sleeves and encapsulating materials are to be made; and the pH of the material. There are a variety of items that may need such testing, from manuscript marking inks to tapes for use in matting. It is also wise to consider how each item will respond to and affect photographic materials in disasters, such as floods or fires.

ANSI has devised a standard, *Photographic Processed Films, Plates, and Papers — Filing Enclosures and Storage Containers, IT9.2-1988*. This standard makes recommendations for filing enclosure materials, and suggests tests to examine the effect of these materials on photographic materials. The "Photographic Activity Test" will be performed in this section.

Alkaline buffered materials are not recommended for some (and perhaps most) photographic materials. It is a simple matter to take a pH reading using a surface probe on a wet spot on the material, to determine the acidity of a paper, and the presence of an alkaline buffer. The "Alkaline Reserve Test for Paper," also included in ANSI IT9.2-1988, allows one to calculate the actual percentage of alkali reserve (buffer) in a sample of a paper enclosure. (This test will not be performed here.)

10.3.2 Experiment 10: Photographic Activity Test

Purpose

To perform the Photographic Activity Test, as outlined in ANSI IT9.2-1988, *Photographic Processed Films, Plates, and Papers — Filing Enclosures and Storage Containers.*

Introduction

The photograph conservator must be sure that filing enclosures to be used with photographs are chemically stable and free of acids and peroxides that may be released slowly with time and cause image loss or chemical decomposition of films or prints. Various tests have been used to test filing enclosures and storage containers. This experiment uses the ANSI Photographic Activity Test to test a plastic negative holder and a paper envelope filing enclosure.

The photographic activity test is designed to test for two different problems that may occur with enclosures. In both cases, chemicals may move out of the storage material and into the photograph. The first test determines if these chemicals react with the image silver or accelerate other reactions with the image silver to produce image loss. The second part of the test determines if any staining of the photograph occurs due to absorbence of chemicals from the storage material by the gelatin of the photograph.

Two special sensitive detectors are used in this test. One is a specially prepared fading detector that contains colloidal silver in gelatin coated on a polyester support. The second detector, used for detecting staining, is any premium grade black-and-white photographic paper that has a thick emulsion and has been processed to its D-min density.

The activity test works by incubating the detectors in close contact with the storage or enclosure material at 70°C ± 1°C and 86% RH ± 2% RH for 15 days. If adhesives are used on seams of enclosures, the detectors must be in direct contact with the inside of the seamed part of the enclosure. This is particularly important, since adhesive materials can be highly reactive with image layers.

In this experiment, sealed glass desiccator jars are used at high temperature. Consequently, it is especially important to wear protective safety equipment. Safety goggles for eye protection must be worn. Special gloves for handling hot equipment must be worn when handling the heated desiccators, and the appropriate gloves must be worn when mixing the saturated salt solution. It may also be required that the desiccator be taped to limit damage from flying debris should breakage, implosion, or explosion occur. Lab coats must be worn at all times.

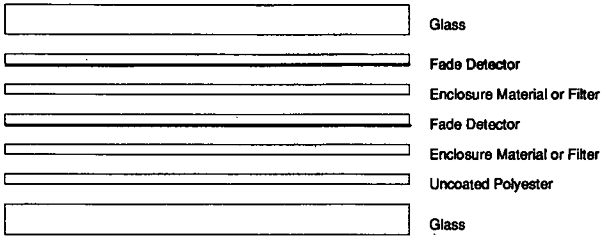
Materials and Apparatus

- 8 fade detectors, 10 × 2 cm
- 8 strips of Kodak Elite Fine Art Paper, #2, 10 × 2 cm
- paper processing chemicals
  - Kodak fixer
  - Kodak Hypo Clearing Agent
- 2 glass jar desiccators
- aging ovens
- saturated salt solution:
  - barium chloride
- filing enclosure samples:
  - polyvinylchloride 3-ring binder pages
- paper envelopes with pasted seam in the center
- Whatman No. 1 filter paper
- uncoated polyester
- 16 sheets of glass, 10 × 2 cm

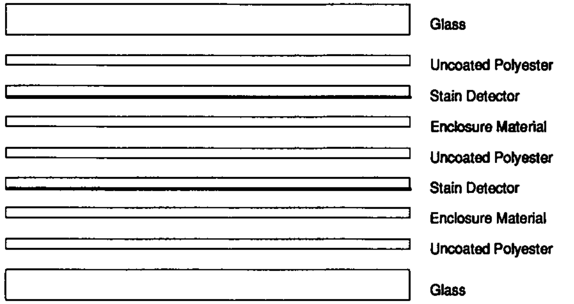
Procedure

1. Turn on the aging oven and bring it to a temperature of 70 ± 1°C. Prepare a saturated solution of barium chloride (see Section 2.6.1). Put the solution in a shallow dish in the bottom of the desiccator. Put the desiccator lid in place, making sure that there is a good seal. Close the stopcock and place the desiccator in the oven for 20 hours prior to the samples being introduced.

2. Prepare the paper samples. Without exposing the samples, process them according to the manufacturer's recommendations. If only processing these samples with fresh fixer, the single bath method is sufficient.



Fade Test Sandwich



Stain Test Sandwich

Fig. 10.5: Layers of test materials for the Photographic Activity Test.

3. Measure and record four Status A blue density readings of each fade and stain detector. Do not take readings near the edges of the detectors. Note the location where each reading was taken so that the same locations may be read later.

4. Once the stain detectors have been prepared, assemble the following four sandwiches using the polyvinylchloride enclosure and the filter paper as the control material.

    1. Fade Test Sandwich
    2. Fade Test Control Sandwich
    3. Stain Test Sandwich
    4. Stain Test Control Sandwich

    Assemble these sandwiches as per the illustrations in Figure 10.5. The emulsion side of each detector must face the enclosure material. In the control sandwiches, substitute the Whatman No. 1 filter paper for the enclosure material.

5. Repeat this procedure, using the paper filing enclosure and being careful that a seam is used in both the fade and stain test sandwiches.

6. Once the desiccators have been conditioned, lay each stack down separately on the rack and place sufficient weights on each stack to produce a pressure of 5 grams/cm^2. Close the desiccators and return them to the ovens. Leave them there for 15 days. Make daily checks on the oven temperature, to ensure that it remains at 70 ± 1°C.

7. After 15 days, remove the samples from the ovens and immediately pull them apart. If the stain detector has adhered to the paper sample, attempt to separate them by briefly soaking them in water and gently rubbing them.

8. Using the light table, make a thorough visual examination of the fade detector for the presence of mottling. Take Status A blue density readings in the same four places on each fade and stain detector.

9. Fading shall be calculated by subtracting the density after incubation from the initial density at each of the four points on the two fade detectors that were in contact with the enclosure material. The mean and standard deviation of these eight differences is then calculated and noted. Repeat this calculation for the two fade detectors in contact with the control filter papers.

10. The stain value is similarly calculated. Find the density change of each location on the stain detectors in contact with the enclosure material before and after incubation. Calculate the mean of these eight values. Repeat this calculation for the stain detectors in contact with the Whatman filters.

11. An enclosure material is deemed to have passed the test if:

    a. There is no visible mottling in the fade detectors.

    b. The fade value of tests is not greater than the fade value for the controls plus two standard deviations.

    c. The stain value of the tests is not greater than the stain value of the controls plus 0.05 density units.

Analysis

Write a brief report on the results of testing these two materials.

10.4 References

Green, A., and G.I.P. Levenson. 1972. A Practical Swellmeter. *Journal of Photographic Science* **20**: 205-210.

10.5 Supplemental Readings

ANSI. 1964. *Determining the Melting Point of a Non-support Layer of Films, Plates, and Papers.* PH4.11-1964 R1981. New York: American National Standards Institute.

ANSI. 1969. *Method for Comparing the Color Stabilities of Photographs.* ANSI PH1.42-1969 R1981. New York: American National Standards Institute.

ANSI. 1972. *Method for Determining the Resistance of Photographic Films to Abrasion During Processing.* ANSI PH4.35-1972. New York: American National Standards Institute.

ANSI. 1977. *Methods for Determining the Scratch Resistance of Processed Photographic Film.* ANSI PH1.37-1977. New York: American National Standards Institute.

ANSI. 1984. *American National Standard for Photography (Film) — Archival Records, Silver-Gelatin Type, on Cellulose Ester Base.* ANSI PH1.28-1984. New York: American National Standards Institute.

ANSI. 1984. *American National Standard for Photography (Film) — Archival Records, Silver-Gelatin Type, on Polyester Base.* ANSI PH1.41-1984. New York: American National Standards Institute.

ANSI. 1986. *Methods for Evaluating Processing with Respect to the Stability of the Resultant Image — Black-and-White Papers.* ANSI PH4.32-1986. New York: American National Standards Institute.

ANSI. 1988. *American National Standard for Imaging Media (Film) — Silver-Gelatin Type — Specifications for Stability.* ANSI IT9.1-1988. New York: American National Standards Institute.

ANSI. 1988. *Photographic Processed Films, Plates, and Papers — Filing Enclosures and Storage Containers.* ANSI IT9.2-1988. New York: American National Standards Institute.

Carroll, J.F., and J.O. Paul. 1961. Test Methods for Rating Abrasion Resistance of Photographic Film. *Photographic Science and Engineering* 5(5): 288-296.

Current, I.B. 1954. Equipment for Testing Some Physical Characteristics of Sensitized Materials. *Photographic Engineering* 5(4): 227-233.

Eastman Kodak. 1982. Dye Stability: Kodak Scientists Discuss Practical and Theoretical Duration. *The Professional Photographer* **109**(2038): 22-26.

Hendriks, Klaus B., and B. Lesser. 1983. Disaster Preparedness and Recovery: Photographic Materials. *American Archivist* **46**(1): 52-68.

Hendriks, Klaus B., et al. Properties and Stability of Gelatin Layers in Photographic Materials. 1984. In *American Institute for Conservation of Historic and Artistic Works Preprints of Papers Presented at the Twelfth Annual Meeting, Los Angeles, California, 15-20 May, 1984,* 52-62. Washington, D.C.: AIC.

Hubbell, D.C., et al. 1967. Methods for Testing Image Stability of Color Photographic Products. *Photographic Science and Engineering* 2(5): 295-305.

Parker, J.T., and L.J. Sugden. 1963. Determining the Resistance of Photographic Emulsions to Damage During Processing. *Photographic Science and Engineering* **7**(1): 41-47.

Tuite, R.J. 1979. Image Stability in Color Photography. *Journal of Applied Photographic Engineering* **5**(4): 200-207.

Wilhelm, H. 1981. Monitoring the Fading and Staining of Colour Prints. *Journal of the AIC* **21**: 49-64.

Roy Thompson Hall.
Toronto, Ontario. 1982.
Fiona Spalding-Smith.
Contemporary print from
color interpositive. National
Archives of
Canada/PA-135205.

11 Condition Reports, Treatment Proposals, and Collection Preservation Surveys

11.1 Condition Reports for Individual Items or Small Collections

11.1.1 Introduction

When a photograph conservator receives a photograph that has been submitted for treatment, for examination prior to acquisition, or for examination prior to exhibition or loan, a report of the condition of the photograph must be written. A condition report identifies the photographic process and materials involved and, if required, enumerates in detail the ways in which the support or image layers have been damaged. In addition, a record should be made of the photograph's original housing or storage container. In many labs, including this one, condition reports also describe proposed treatments for the object being examined.

The condition report documents an important part of a photograph's conservation history. It provides one kind of evidence of before-treatment condition and should be concrete and detailed. Accompanying most condition reports is photographic documentation providing a visual along with a written record of the object. In some cases, densitometrically controlled black-and-white photographs are required, but in others, 35-mm transparencies will suffice.

Condition reports are not used for large photographic collections, but rather for single-item examinations and occasionally for small collections. There are exceptions: for example, if a large collection of cellulose nitrate negatives requires some preservation or storage attention, and all items will receive the same treatment, it is appropriate to use a sampling from the large collection as the basis for a single condition report that describes the materials and their state of deterioration. However, most large collections consist of a mixture of processes and materials, few of which will receive individual conservation treatment. In these cases, it is appropriate to conduct a survey of the collection, to determine its preservation needs. Methods for surveying collections are discussed in Section 11.3.

11.1.2 Photographic Documentation: Before, During, and After Treatment

An integral part of preparing condition reports and performing treatments is photographic documentation. Before, during, and after treatment photographs should be part of the permanent record of the object. Before treatment photographs not only document the pretreatment condition, but may act as surrogate images in the event of loss or damage during treatment. During treatment shots record damage that may be uncovered during the course of treatment. Occasionally, ultra-violet and infra-red photographs may be required in an attempt to enhance faded inscriptions or discern photographic images lying underneath a paint layer. If an unusual treatment is to be carried out on an object, photographic documentation of the treatment can be a valuable reference tool for the future. After treatment shots can serve to monitor the condition of an object after it leaves the lab.

For most routine lab work, 35-mm transparencies, properly color balanced, will suffice. For more valuable objects and large scale projects, 4" × 5" transparencies and 4" × 5" black-and-white negatives should be taken. Again, the color must be accurate and the black-and-white negatives processed for permanence. Four-by-five-inch documentation is certainly preferred for all objects, but it is expensive and impractical for a large volume of material.

Documentary photographs, particularly color, must be protected from adverse environmental conditions, which may mean cold, dark storage. They are intended as permanent records and should be stored as such.

11.1.3 Identification of Photographic Processes and Materials

An accurate identification of the process by which a photograph was produced is required for a condition report. Chapter 5 discusses the history and technology of many contemporary and historic photographic processes and provides a bibliography for further investigation. The chapter also describes a variety of tests that can be used to assist in process identification including spot tests (aqueous and non-aqueous), flotation test, burn test, and polarization test. Some spot testing may be needed to distinguish between a collodio-chloride and studio proof print, or between a wet collodion and gelatin dry glass plate negative, for example. Spot tests must be carried out on an unimportant area of the image. Destructive tests should not be carried out on original materials unless absolutely necessary and only after discussions with curatorial and custodial staff. With rare photographs, no test should be administered without curatorial approval, if that test will alter even slightly the picture's appearance.

Comparing unknown photographs with items that have known identities can also yield clues as to the process in question. Chapter 7 could provide information, as a discussion of conservation treatments also includes the types of damage that may be found on specific materials such as case photographs, glass lantern slides, negatives, etc.

Identifying a process may simply require a microscope or magnifier. The conservator should specify in the condition report the tests and criteria that were used to positively identify less common processes and particularly if any doubt exists.

The following table lists a number of tests that can be administered to assist in the identification of photographic processes and materials and are described thoroughly in Chapter 5.

Identification Tests

Spot Test
Aqueous — Test for gelatin emulsions — non-destructive test
Non-aqueous — Alcohol test for collodion materials — destructive test

Flotation Test
Differentiates between plastic film bases — small sample required — destructive test

Burn Test
Differentiates between plastic film bases — small sample required — destructive test

Polarization Test
Differentiates between plastic film bases — non-destructive test

Cross-Section Analysis
Examination of the structure — destructive test

Microscopic Analysis
Visual examination through microscope — non-destructive test

Radioisotope-Excited X-ray Energy Spectrometry (REXES)
Elemental analysis — non-destructive test

Fourier Transform Infra-red Spectrometry (FTIR)
Elemental analysis — non-destructive test

11.1.4 Description of Items

The purpose of the condition report is to fully document an object's condition. The documentation of its aesthetic or historic value is an area generally left to curators. However, it is important for the conservator to be aware of an object's relative rarity or research importance as this may affect the manner in which it is housed and the choice of environment in which it is to be stored. For example, a heavily used item in a research collection should be matted for maximum protection and not stored in a cold storage vault. Also, a photograph's monetary value may dictate extra security precautions.

Describing an object begins with a title if it exists, or a brief description of the subject, composition, etc., the artist's name and date, and the dimensions. This is followed by a description of the process or method of production, materials used, and finally condition of the materials. The components of a photograph are generally described under the following headings: image forming substance, binding medium, interlayers, surface layer, and supports. The support layer is further broken down to: primary support, secondary support (mount boards, etc.), and auxilary supports (tertiary supports, stretchers, etc.).

Condition reports should include as much information as is possible and should reflect a thorough understanding of the materials. The tests and criteria used to determine the process or composition of the object should also be noted.

Under "surface layer," inscription labels and imprints are recorded. The type of inscription, medium used, and location should be noted. This, of course, holds true for inscriptions on secondary and auxilary supports. The location and medium of an inscription, aside from its historical value, can affect the choice of treatment an object receives. Mounting a photograph on a new support could cover up an inscription that the curator may wish to keep exposed, or the medium may be water soluble, precluding the use of aqueous mounting adhesives. Any special attributes of the image must also be well documented including: handcoloring and retouching, collage elements adhered to the image, and surface characteristics such as the finish of the binding media (mat, glossy, textured, etc.). Areas of special interest or unusual features should also be thoroughly photographically documented. In most cases, correctly color balanced 35-mm transparencies should suffice. As indicated in the introduction, complete photographic documentation should be carried out regardless of the value of the object. Four-by-five-inch transparencies and black-and-white negatives of both recto and verso of the object are preferred, but are not always practical, particularly for a large collection.

11.1.5 Analysis and Assessment of Damage

Mechanisms of Deterioration: A Review

The kind of damage that may occur to photographs is discussed and enumerated in detail in Section 3.3, as are the two basic mechanisms of deterioration, mechanical damage and chemical deterioration.

Mechanical Damage: Includes anything that alters the physical structure of the photograph: rips, tears, abrasions, accretions, curling, peeling, cracking, wrinkling, flaking, desiccation, reticulation, embrittlement, defacement, "tide lines,"etc. These kinds of damage can result from poor storage conditions, careless handling, improper repairs, and insect or rodent attack.

Chemical Deterioration: Refers primarily to the chemical alteration of the image-forming substance. This includes staining, fogging (chemical and dichroic), fading (in light and dark storage), redox blemishes, silvering-out, and evidence of fingerprint marks, etc. These kinds of deterioration result from poor processing procedures, atmospheric pollution, poor storage conditions and inappropriate enclosure materials, general careless handling, and in some cases, biological attack (mould, fungus, etc.). It also refers to the inherent instability of certain types of materials such as cellulose nitrate and cellulose diacetate.

Assessment of Damage

Photographs usually consist of two principal layers, the support and the image-bearing layer. As outlined in Chapter 5, some image-forming substances are embedded in the paper fibres of the support, while some are embedded in a binder that sits on top of the paper fibres (generally referred to as the emulsion). Between the emulsion and the support is the baryta layer found on most gelatin and collodio-chloride prints. Interlayers or subbing layers between the emulsion and film base must also be considered for certain film types. Recording the assessment of the damage should follow these logical divisions (i.e., layers), although it should be made clear that damage to one part can affect another. For example, a rusting tintype support (iron) can cause the collodion emulsion to blister; deterioration of the cellulose nitrate subbing layer and the cellulose diacetate base can cause deterioration and dimensional changes that result in the warping and buckling of the film emulsion; a broken glass plate support tears apart the emulsion adhered to it. The kinds and causes of deterioration are enumerated in Sections 3.3.2 and 3.3.3.

The type, location, and degree of damage or deterioration must be clearly indicated, using terminology that will be easily understood by conservators and curatorial staff. When it is practical and possible to carry out diagnostic tests on the condition of the photographic materials involved, the test methods and results should be provided.

During this damage assessment procedure, the conservator must keep in mind the possible causes of the damage as this may have an impact on the selection of potential treatments. For example, if a decorative mat is abraiding the surface of a print and the curator insists on returning the object to that mat, modifications will have to be made to the mat to protect the print emulsion.

One should make note of and describe the container or enclosure in which the photograph was stored, if this information is available. This can provide clues to the causes of deterioration and damage. Damage by local ferrotyping to a framed photograph points not only to poor framing methods, but to storage in conditions of high or fluctuating relative humidity and temperatures. There may be a cause-and-effect relationship between a sulfided silver gelatin photograph and its acidic paper filing enclosure.

To better assess the condition of an object, an attempt should be made to determine the environmental conditions under which a particular photograph or collection was stored previously. For example, if a collection of glass plate negatives was stored unprotected in a barn for several years, one may assume that water damage has occurred, as well as problems caused by alternate freezing and thawing, or possibly damage from rodents, insects, birds, abrasion from dust, etc.

Conservation Treatment History

Maintaining accurate records of treatments performed on an object is essential. They can assist in the assessment of damage to an object in the future and should provide future conservators with a thorough understanding of the conservation materials and processes used on an object. Conversely, when examining an object that has been conserved in the past, any existing record of the treatment should be carefully scrutinized for clues as to what treatments were performed and what materials were used.

A damage assessment provides an occasion to make a record of the photograph's treatment history. For example, if it is known (or indicated) that a daguerreotype was cleaned by chemical or physical methods, and if new seals are in place, this should be noted. If repairs to torn photographs are evident, they should be examined and analysed for the role these repairs played in determining the photograph's present condition: were proper tapes or adhesives used? Is in-painting evident? Was a new support applied?

When examining an object previously treated, aside from assessing the damage to the object that has occurred following treatment, the conservator must also assess the damage that occurred prior to treatment and, if necessary, treatment proposals must also include undoing previous conservation treatments. The existence of duplicates or surrogate copies will also affect a treatment proposal. Previous photographic documentation can provide a guide to the conservator as to the look of the object prior to the present damage or prior to an inappropriate treatment.

11.2 Treatment Proposals and Reports for Individual Items and Small Collections

11.2.1 Introduction

The treatment proposal is based on the findings described in the condition report and on standard procedures developed within the lab. For example, if it is standard practice within the lab to mat every object following treatment, this would be part of the treatment proposal despite the fact that sleeving would be a satisfactory storage solution. The treatment proposal is a series of recommendations for a complete treatment laid out in logical, sequential order. A full treatment should be outlined unless specifically requested otherwise so that if a partial treatment is decided upon, recommendations for further treatment have at least been noted indicating that the conservator is fully aware of the needs of the object. Budget constraints, space limitations, and other more pressing demands on the conservator's time can result in a somewhat less than complete treatment for an object.

Due to the complex nature of photographic materials and the fact that it is a relatively new field, few treatment precedents have been set. The student must be prepared to spend time investigating new methods and procedures and to be somewhat innovative when developing treatment proposals.

A completed treatment report includes a detailed account of the actual treatment performed, photographic documentation, and any other supporting documentation. Analytical reports from analysis conducted on the object both in outside labs and internally should also be included.

11.2.2 Treatment Proposals

Treatment proposals for most items should be developed in consultation with curatorial staff. If an object is required for exhibition, the curator may have specific mounting requirements. The treatment of albums, for example, will be very much affected by curatorial concerns such as the value of the album format, whether the original album should be conserved or a new one made, or whether the prints should be mounted permanently or in such a way that they can be easily removed for display. Housing must also be jointly decided upon, as space limitations, for one, may dictate the use of one method over another. Also, the relative value of the image may affect the extent of the treatment performed. For example, a print of little intrinsic value may not be retouched following consolidation or a valuable print may be matted for storage as opposed to being simply sleeved.

If a conservator is having problems devising a treatment proposal for an object as a result of some characteristic of the material, it may be necessary to study the literature on treatments that may be appropriate and could be adapted for use. Consulting with other conservators in the field may also yield useful treatment alternatives. However, when considering treatments with which one is not familiar, the conservator must plan to conduct tests and experiments on disposable materials prior to recommending them.

Treatment proposals are first submitted to the senior conservator and then forwarded to the custodian or curator for approval. This requires that the report be written in clear, concise language using accepted terminology. Basic paper conservation and photographic technology terms should be used as they have specific meanings relevant to the subject at hand. Contemporary photographic materials and processes have been clearly defined and named by industry. When dealing with historic items, however, in many cases several terms exist for the same thing. Although no complete glossary of photograph conservation terms has been compiled to date, the Supplemental Readings at the end of this chapter list several thesauri that the student may wish to consult. Also, many books and articles published on photograph conservation contain small glossaries that also may be consulted.

If several treatment options are being presented to the curator or custodian, sufficent information should be forwarded to allow them to make informed decisions. The presentation of several treatment options is generally required only for major projects where full treatments may have a substantial impact on resources such as time and materials.

Most condition reports include the treatment proposals. However, in the event that the treatment proposal is submitted separately, some indication of the condition must be reported. If a full condition report exists as well, the inclusion of a condensed version is sufficent.

Although a treatment proposal could be adapted for use with a large collection, where a series of actions or treatments will be carried out on all photographs or negatives in that collection, its primary use is to propose treatments for single images.

The following is a list of standard treatments that are performed routinely on photographic materials. It is intended as a quick reference list and does not preclude the use of new or adapted treatments from other disciplines.

Checklist of Treatments

Sensitometric Copying and Duplicating Procedures

- Negative and lantern slide duplication, including the use of internegatives, density masks, and direct duplicating procedures
- Production of high-quality copy negatives and prints, matching closely the density range of the original image
- Stain "removal" by copying with filters
- Corrective duplication and printing of stained historical negatives

Paper Conservation Treatments

- Aqueous and non-aqueous surface cleaning
- Dry surface cleaning
- Dismounting of photographs
- Removal of tapes and adhesives
- Washing of prints and mounts, and negatives
- Tear repairs
- Filling and compensating for losses
- Flattening of curled prints and negatives
- Application of new support or backing
- Repair of cracked and lifting emulsions
- Repair of broken glass negatives and lantern slides
- Retouching of repaired photographs
- Matting
- Framing
- Treatment of decorative photographic cases and the images they contain
- Treatment of painted photographs
- Encapsulation
- Encapsulation and post-binding
- Treatment of photographic albums

Treatments and Procedures Derived from Photographic Technology Methods

- Emulsion transfer for negatives on deteriorating film bases
- Pre-treatment laboratory tests and analytical instruments, to determine the nature and condition of photographic materials
- Scientific monitoring methods for use during certain treatment procedures
- Tests for determining and monitoring the effects of display and storage conditions on photographs and storage materials
- Chemical treatments, where appropriate:
  Intensification
  Reduction
  Harmonization
  Chemical Restoration (Bleach and Redevelopment)

11.2.3 Treatment Report

The conservation work begins only after the curator and supervisor have approved and signed the treatment proposal. During treatment, the conservator must make notes on what was done, specifically, and what occurred during treatment. It is important to note any unanticipated responses or results. If damage occurred, the conservator must report it in full detail.

This information must be given using standard photographic and conservation terminology, and it must be given in enough detail to provide future curators and conservators with a useful record of the object's treatment history and explain how and why it came about. Treatments that are considered acceptable and ethical by today's standards may be deemed unnecessary or deleterious to the object in the future. For this reason, one of the basic requirements of any treatment is that it be reversible. In the event that a treatment needs to be reversed in the future, a complete history, including treatment record, of the object would facilitate, and in some cases be the key to, its undoing. Conversely, the value of an object may increase dramatically as the result of treatment and accurate records may be a key to maintaining its value.

11.2.4 Sample Condition/Treatment Proposal Form

For an example of a condition/treatment proposal form, refer to the next page. The actual form used will vary among institutions, depending on the nature of their collections, the facilities available for conservation work, and the requirements of the museum, archive, or library conservation staff. Many institutions are now compiling all of their condition/treatment information directly onto a computer, which also affects the form in which it is recorded. If it is a database, using standardized terms is essential as these become searchable fields. If it is a word-processing system, it becomes less crucial. Some forms use a "check box" format or "codes" to record damage and treatment recommendations while others use free text. One is not recommended over another. What is important is that terminology be consistent.

Ideally, the form, whether computer-generated or handwritten, should be produced on acid-free paper with permanent inks or graphite as it is intended as a permanent record. (Only pencil notes should be taken in the vicinity of photographs, however.) The original copy of the forms should be stored with the photographic documentation in a specified location, and if not stored together, their location must be clearly indicated. If it is not standard policy to produce a "hard" copy of each report, it is essential that the computer-generated reports be "backed up" onto separate diskettes.

CONDITION AND RECOMMENDED TREATMENT REPORT
PHOTOGRAPH CONSERVATION LAB

ACC. No. PCD No.

ARTIST/ATTRIBUTION:

TITLE/DESCRIPTION:

DATE: EXAMINED BY:

PROCESS:

CUSTODY:

EXAMINATION: PHOTOGRAPH HOUSING

FRAME:

MAT:

PROTECTIVE BACKING:

GLAZING:

OTHER MATERIALS:

EXAMINATION: PRIMARY SUPPORT

PRIMARY SUPPORT TYPE: (*) DETAILS/COMMENTS

Fibre ....
Polyester ....
Resin-Coated ....
Other ....

DIMENSIONS (cm): PRIMARY SUPPORT: L W IMAGE: L W

SURFACE CHARACTERISTICS:

METHOD OF ATTACHMENT: (Primary to Secondary Support)

WATERMARK:

EXAMINATION: SECONDARY SUPPORT

SECONDARY SUPPORT TYPE: (*) DETAILS/COMMENTS

Album Leaf ....
Pasteboard ....
Acid Groundwood ....
Rag ....
Illustration Board ....
Other ....

INSCRIPTIONS:

EXAMINATION: IMAGE (CARRYING LAYER)

SURFACE: (*) DETAILS/COMMENT

Tinted ....
Handcolored ....
Collage ....
Coated ....
Other ....

CONDITION

HOUSING:

PRIMARY SUPPORT: (*) LOCATION/DESCRIPTION:

Satisfactory ....
Surface Dirt ....
Stains ....
Foxing ....
Matburn ....
Water Damage ....
Mould Damage ....
Insect Damage ....
Tears ....
Losses ....
Punctures ....
Dog-eared ....

CONDITION

HOUSING:

PRIMARY SUPPORT: (*) LOCATION/DESCRIPTION:

Embrittlement ....
Dents, Creases ....
Reg. Wear and Tear ....
Other ....

IMAGE (CARRYING LAYER): (*) LOCATION/DESCRIPTION:

Satisfactory ....
Frilling (edges) ....
Flaking ....
Cracked ....
Crackle ....
Scratched ....
Abraded ....
Losses ....
Foreign Marks ....
Accretions ....
Fading ....
Silvering ....
Other ....

RECOMMENDED TREATMENT: (*) DETAILS/COMMENTS:

Treatment not required ....
Remove from present mount ....
Remove from s. support ....
Mount ....
Mat in non-buffered board ....
Surface clean ....
Stain removal ....
Repair Tears ....
Infill losses ....
Compensate ....
Other ....

PICTURE CONSERVATION DIVISION *NATIONAL ARCHIVES OF CANADA*

11.3 Surveying Large Collections for Preservation Needs

11.3.1 Introduction

A large collection is defined, for our purposes here, as a collection of such a size that individual conservation treatment for items is not feasible. (This does not preclude the possibility that individual items in a large collection should and will receive individual conservation treatment.)

In many institutions, the curator or custodian faces the task of giving some level of protection to extremely high volume collections, such as a newspaper photo "morgue" of one million pictures, some hastily processed, with no corresponding negatives; the 35,000 wet collodion and dry plate glass negatives from a 19th-century studio photographer, which have suffered extensive damage from storage in a barn; the 70,000 prints and negatives (albumen photographs, cyanotypes, platinum prints; glass plate, nitrate, and safety film negatives) of a turn-of-the-century photojournalist and portrait photographer; or the 500,000-item documentary survey of architecturally significant buildings, produced on modern silver gelatin sheet film and paper. On a smaller scale, one might find among the papers of a public official some 10,000 photographs, many mounted on albums of poor-quality paper; or 500 photographs from among the memorabilia of a famous aviator; or 100 negatives documenting the last years of an Indian reservation.

In these situations, proposals for individual conservation treatment for each item would be impractical. Nor is it acceptable for the conservator to simply advise that collections be put away until ideal solutions can be implemented. Therefore, the consulting photograph conservator must be prepared to find some preservation solution that will help to extend the life of larger collections of artistic and/or historical photographs.

The photograph conservator can offer his or her knowledge and experience to the curator faced with the task of estimating the cost of preservation care for large collections. The conservator should be familiar with the cost of various preservation materials and the commercial suppliers thereof and should advise custodians about the quality and appropriateness of various kinds of filing enclosures and storage solutions. Part of the conservator's duties, then, should be to collect information about, manufacturing specifications for, and samples of various filing enclosures and storage boxes, and their materials. In addition, catalogues from archival suppliers for libraries and museums should be kept on hand and up-to-date, so that price information is current.

Some large collections in need of preservation already may be in use by researchers. Other collections may have been in the institution's dead storage areas for years, or only recently acquired. In some cases, the conservator may be called in to assess the needs of a collection before it is acquired by the institution; the results of a preservation survey may be used to decide whether to acquire a gift or purchase. Also, surveys are conducted on many research collections on a regular basis to monitor the effects of circulation on these items.

The institution may need this information to formulate a request for funding or to direct a continuing conservation program. These examples illustrate the wide range of collections and occasions for surveys.

11.3.2 Preservation Survey Report

Although the collections will vary enormously, the basic information to be obtained for full-scale preservation surveys will not. However, the scope of a survey can vary considerably; for example, one may simply wish to determine the types and numbers of photographic materials present in order to establish proper environmental conditions. The rest of the information may be known and recorded elsewhere. This section discusses the range of information that may be required for the Preservation Survey Report.

Brief description of the collection, its provenance, and known value (historical or artistic), and date range

The curator will provide most or all of this information, which should be provided in brief in a preservation survey. Curatorial appraisal guidelines are discussed in Horvath (1981). One should mention, for instance, the photographer(s) represented, and the conditions under which the photographs were produced (e.g., Arctic exploration survey photographs, family snapshots, etc.). Newspaper photo archives usually require less elaborate or expensive filing enclosures than fine art photographs. Photographs of great rarity or value (such as the unretouched proof photographs produced by the Indian photographer, Edward Curtis) will probably be housed differently than modern silver gelatin copy photographs for use in library "browsing files."

Information should be provided, if possible, about the actual date range of the material. After sampling the collection, try to estimate the date range represented by the bulk of the material. Indicate the status of the material: is it restricted by copyright protection or by the terms of the acquisition agreement? Can researchers use the materials? Can photographs be reproduced? This will help the institution determine its preservation priorities. Provide whatever general information will be needed to help curators, custodians, institution administrators, and granting agencies to place the collection in its proper historical or artistic context and to evaluate the relative research and money value of the collection.

Rarely would a conservator be asked to provide this type of information, but it is included as an example of what may be required as part of a full preservation survey. Not all will include this information as it is dependent on the reasons for and the overall scope of the survey.

Brief description of the state of acquisition, processing or use of the photographs

If the collection has been in storage for 25 years, or is currently being used, despite the lack of preservation housing, or is part of a newspaper archive in use until last year, mention these facts. Indicate, for example, if only part of the collection has been received, with the expectation that more will arrive next month, or a decade from now. Describe briefly the physical arrangement of the materials: chronological? alphabetical? geographical?

Description of the material in the collection

State only the basics: glass or film negatives; paper or resin-coated prints; case photographs; photographically illustrated books. Give as accurate an estimate of the number of items as possible. Provide a description of the sampling and extrapolation methods used to arrive at this estimate. Indicate for example, whether you counted one roll of 35-mm negatives as 36 separate images or one item; indicate how many glass negatives were found to equal one linear foot of shelf space; indicate how many silver gelatin prints are found in a single vertical file cabinet drawer and so forth.

Description of the photographic processes represented

Without examining each item in the collection, enumerate those processes that are represented in sample portions of the collection, and give their approximate numbers as a percentage of the whole: i.e., silver gelatin photoprints (80%); cyanotypes (10%); 35-mm roll-film negatives (5% of volume); case photographs (5%).

Size range represented

To order preservation supplies, one needs to know the range of sizes represented and the approximate percentage of the collection that each standard size represents: 8" × 10" (75%); 4" × 5" (20%); 16" × 20" (5%). If collections contain large numbers of encased images, cabinet cards, or *cartes-de-visite* photographs, this should be noted, because supplies are available for standard 19th-century formats; similarly, odd-size items, like panoramic photographs, should be noted, even if they represent a small percentage of the whole.

Present storage conditions

Describe the present filing enclosures, frames, boxes, filing cabinets, and other kinds of housing. Give a full description of their present storage location and environment.

Past storage conditions

Make note of any less-than-favorable storage environments in which the collection has been housed. This information may be brought to bear in deciding what preservation materials and storage methods to use with the photographs.

Identifying information found on or with the material

If studio log books are stored with the collection, or inscriptions are written on photographs, or labels are paper-clipped to prints, or news agency captions are glued to negative jackets, make note of this information. These conditions may make certain kinds of filing enclosures and storage inappropriate and may complicate the preservation processing of the materials.

Significant or wide-spread damage

Report evidence of damage or preservation problems that are represented on a sizable portion of the collection. For example, one would indicate that 50% of the glass negatives in a collection exhibit flaking or lifting emulsions or that 25% are broken; that 80% of the photographic prints are mounted on acidic and brittle mount boards; that pressure-sensitive cellophane tape has been used to mount hundreds of snapshots in a family album; that 60% of the daguerreotypes lack cover glasses; that the earliest portion of a chronologically arranged collection of film negatives is on a cellulose nitrate base and shows signs of the early stages of deterioration, or that 75% of the silver gelatin prints show rodent or insect damage.

This is a different kind of report than the careful and detailed examination for a single-item Condition Report, where every loss, tear, or stain is described.

Under this category of information, include other kinds of observations that may be pertinent such as: the entire collection of 50-year-old silver gelatin photographs gives off a strong fixer-like odor; or the negative collection gives off an odor of nitric acid; or the gelatin emulsions feel tacky or sticky; or the storage envelopes and captions written thereon crumbled easily during even careful handling. Provide a general assessment of the general condition of the materials, noting exceptions if necessary: very poor, good, excellent. One may even wish to red flag certain materials for immediate action (such as isolating a stack of deteriorating nitrate negatives from the rest of the collection). It is important to identify inherently unstable materials in order that proper storage materials and environmental conditions be planned.

Preferred storage materials or formats

If the curator wants every print matted, or the institution now can accommodate only vertical manuscript boxes or vertical filing cabinets, this will play a major role in determining what solutions can be implemented. If the institution has no shelf space, but materials must be stored horizontally, the conservator should be available for consultation about the design of and materials for shelving. Likewise, suggestions should be made for interim solutions, if map cases or filing cabinets cannot be immediately obtained, for example.

Preservation supplies needed

Suggest various appropriate supplies and their cost per item, or per hundred items. Suggest alternatives and the advantages and disadvantages of each. Naturally, one can't anticipate every need on the basis of a sampling, but one can present a "ballpark" figure. Do we need acid-free paper storage envelopes (20,000 5" × 7", 5,000 8" × 10", and 1,000 11" × 14") for a glass negative collection? Will envelopes or folders have to be specially manufactured for a collection of 18" × 22" glass plate survey negatives? Can they use cheaper commercially manufactured 2 mil Mylar sleeves rather than specially manufactured 4 mil Mylar sleeves to protect news agency photographs that will be supported by file folders in vertical manuscript boxes? What is the cost of mount boards for use with collections stored vertically in filing cabinets? It is clear that no suggestions can be made until the conservator knows the storage preference of the institution, research use of the collection, relative value of the items, budget and storage space limitations of the institution, and number and kinds of materials represented.

Storage space requirements

Photographs in archival filing enclosures require more storage space than unprotected photographs. Matted photographs require horizontal storage space in a much greater quantity than encapsulated photographs stored vertically in a box. Provide an accurate estimate of the amount and kind of storage space the collection will require, once it has been properly preserved. It may be useful to sample the space required by 100 unsleeved negatives compared to 100 in paper jackets, for example.

Special preservation solutions pertinent to the collection

Suggest options that may be feasible with this particular kind of material such as: Can glass negatives be microfilmed for research use? Can photographs be microfilmed to save handling? Does the institution have access to the latest technology for reproducing photographs and negatives? Can duplicate images be culled, to lower the number of filing enclosures required? Can rolls of nitrate 35-mm negatives be duplicated at motion picture duplication facilities? Can deteriorated images be copied or duplicated? Can the information from caption-bearing acidic negative jackets be photocopied onto new, acid-free enclosures?

The presence of significant numbers of color or nitrate materials may require special storage procedures and areas.

Procedures that cannot be carried out in-house should be specified. Can nitrate or glass negatives be duplicated outside the institution, under contract? What insurance and transportation costs would be incurred? Provide the names of conservation institutions or independent parties who can carry out this work.

If the bulk of the materials involved require storage and/or display under specific light, temperature and relative humidity levels, this should be recommended.

Estimate the staff time needed to implement certain preservation requirements

The conservator is in a good position to give estimates for the various procedures. How long does it take to slip 100 photographs into commercially produced Mylar sleeves? (If processors must also transfer caption information to the backs of photographs or create labels for sleeves, this will affect the speed at which the work can be done, and should be noted.) How long does it take to mat a single photograph? How long does it take to microfilm 1000 glass negatives (including, where relevant, the preparation time for the collection-sleeving, captioning)? How long does it take to dry-mount 100 modern copy photographs for use in vertical "browsing files." What amount of time is required to duplicate 50 negatives, once they are sorted into similar density ranges? If large work spaces (and special equipment) are required to encapsulate panoramic photographs, or to clean glass negatives, this should be noted.

The final report on the preservation requirements of a large photograph collection can follow the basic structure provided above. However, one might preface the lengthier document with a one-page statistical report that provides a summary of the number of items of each process, materials, and format, the cost of various supply items, the time required to implement the procedures, and the storage space requirements. This information will be provided in greater detail, with explanations where required, in the report itself. The curator or custodian may also require information from published sources on the nature and stability of the materials in the collection, using this information to assist in the planning of future storage facilities and possibly to affect their acquisition policy.

11.3.3 Sampling Methods

It is not possible to describe sampling methods here that can be used in each and every situation. The methods used will vary with the scope of the survey, the size of the collection and the kind of materials found therein (Calmes, 1983-84). (This unpublished report provides a conceptual model for a large-scale institution-wide preservation survey.) Some statistical methods have been developed for libraries and archives, to estimate the size of book collections, required shelf space, and manuscript holdings, without actually counting each item (Abraham, 1985). Most of these methods have been designed for estimating processing time, rather than to estimate the cost and space required to house a collection to archival standards. Photography collections present the same kind of challenge: it would take nearly as much time to count each negative as it would to place it in a paper jacket; item-by-item counting is not only impossible, in many cases, but a waste of time, when accurate estimates can be derived by sampling parts of the collection and multiplying the findings.

In general, one has to fit the sampling and estimating methods to the nature of the collection. One should first look in all of the boxes and containers, to be sure each kind of material has been accounted for. The specific sampling method used for each kind of material must be written down and tested for accuracy: if X-number of inches (in depth) of photographic prints equals X-number of items, one should first count that sample, to determine the rate of accuracy. Are all of the prints double-weight or single-weight? Are some sleeved and some bare? Are some mounted? Are photographic negatives stored more than one to a sleeve? These variances can throw the estimate off by more than 100%, rendering it useless and, worse, introduce serious problems for the curator or custodian. If one person estimates a negative collection at 250,000 items, and it turns out to be 30,000 items, the institution may find itself with 220,000 unneeded acid-free enclosures.

The method for estimating the particular collection and the various kinds of materials and formats represented therein should be given as part of the preservation survey report, as described in Section 11.3.2. above.

11.4 References

Abraham, T., et al. 1985. What Is Backlog Is Prologue: A Measurement of Archival Processing. *American Archivist* **48**(1): 31-44.

Calmes, A. 1983-1984. *Preservation Priorities for Textual (Paper) Records at the United States National Archives*. Unpublished report. Washington, D.C.: National Archives and Records Service.

Horvath, D. 1981. Archival Appraisal of Photographic Materials. *Picturescope* **29**(2): 44-47.

11.5 Supplemental Readings

Canadian Government Specification Board. Committee on Graphic Arts Terminology (Photography). 1972. *Glossary of Photographic Terms in General Use in the Graphic Arts*. Canadian Government Specifications Board, No. 94-GP-1. Ottawa: Canada, Dept. of Supply and Services.

Spencer, D.A. 1973. *The Focal Dictionary of Photographic Technologies*. 1st ed. London: Focal Press.

Vogt, Diane. 1987. *A Draft Photographic Thesaurus*. Smithsonian Archives Photo Survey Project. Washington, D.C.: Smithsonian Institution Archives.

Zinkham, Helena, and Elizabeth Betz Parker. 1986. *Genre/Form and Physical Characteristics Terms: A Thesaurus for Prints, Photographs, Drawings, Ephemera, and Other Graphic Materials*. Washington D.C.: Library of Congress.

Bibliography

Anon. 1860. Duchochois' Dry Collodion Process. *American Journal of Photography and Allied Arts and Sciences* (New York) 2(19): 300-303.

Anon. 1860. Toning. *American Journal of Photography and the Allied Arts and Sciences* (New York) 2: 270-271.

Anon. 1860-1861. Albumenising Paper. *American Journal of Photography and Allied Arts and Sciences* (Philadelphia) 3: 165-166.

Anon. 1860-1861. Richard's Albumen Negative Process. *American Journal of Photography*, n.s., 3: 382-383.

Anon. 1877. How to Clean Daguerreotypes. *Practical Photographer* 1(7): 224-225.

Anon. 1880. Some Practical Receipts. *Photographic Times* (New York) 10(116): 173-174.

Anon. 1935. The Person Process. *Photographic Journal* (London) 75: 569-570.

Anon. 1950, Feb. Copies Without Glare: A New Technique in Copying Uses Polarized Light to Eliminate Surface Reflections. *Modern Photography*, 48-49, 110.

Anon. 1975, Dec. 26. The Lowly Tintype. *British Journal of Photography*, 1168-1170.

Anon. 1981. Calm, Very Cool and Collected ... To Save Film Legacies. *Technology and Conservation* 6(1): 5-6, 8.

Anon. n.d. *Reducers and Intensifiers*. Source unknown, 113-121.

Abney, W. 1894. *Platinotype, Its Preparation and Manipulation*. London: Sampson, Low, Marston and Co.

Abney, W. 1905. *Instruction in Photography*. 11th ed. London: Iliffe & Sons.

Abney, W., and H.P. Robinson. [1888] 1973. *The Art and Practice of Silver Printing*. [London: Piper & Carter]. Reprint. New York: Arno Press.

Abraham, T., et al. 1985. What Is Backlog Is Prologue: A Measurement of Archival Processing. *American Archivist* **48**(1): 31-44.

Adams, Ansel. 1983. *The Print.* New Ansel Adams Photography Series, book 3. Boston: Little, Brown.

Adelstein, P.Z., et al. 1970. Preservation of Motion-Picture Color Films Having Permanent Value. *Journal of the Society of Motion Picture and Television Engineers* **79**: 1011-1018.

Adelstein, P.Z., and J.L. McCrea. 1981. Stability of Processed Polyester Base Photographic Films. *Journal of Applied Photographic Engineering* **7**(6): 160-167.

Agfa-Gevaert. 1989. Letter to author, 19 January 1990.

Albright, G. 1985. Which Envelope? Selecting Storage Enclosures for Photographs. *Picturescope* **31**(4): 111-113.

Anderson, Paul L. 1938. Hand-Sensitized Palladium. *American Photography* **32**: 457.

Anderson, Paul L. 1939. Special Printing Processes. In *Handbook of Photography*, ed. by Keith Henry and Beverly Dudley, 466-506. New York: McGraw-Hill.

Anderson, Paul L. 1940. Palladium vs. Silver for Photographic Prints. *Photo Technique*, Aug., 58-61.

ANSI. 1964. *Determining the Melting Point of a Non-support Layer of Films, Plates, and Papers.* PH4.11-1964 R1981. New York: American National Standards Institute.

ANSI. 1969. *Direct Viewing of Photographic Color Transparencies.* ANSI PH2.31-1969. New York: American National Standards Institute.

ANSI. 1969. *Method for Comparing the Color Stabilities of Photographs.* ANSI PH1.42-1969 R1981. New York: American National Standards Institute.

ANSI. 1972. *Method for Determining the Resistance of Photographic Films to Abrasion During Processing.* ANSI PH4.35-1972. New York: American National Standards Institute.

ANSI. 1973. *Method for Determining the Brittleness of Photographic Film.* ANSI PH1.31-1973 R1979. New York: American National Standards Institute.

ANSI. 1976. *Viewing Conditions for Photographic Color Prints.* ANSI PH2.41-1976. New York: American National Standards Institute.

ANSI. 1979. *Specifications for Thermally-Activated Dry-Mounting Tissue for Mounting Photographs.* ANSI PH4.21-1979. New York: American National Standards Institute.

ANSI. 1981. *Practice for Storage of Processed Photographic Plates.* ANSI PH1.45-1981. New York: American National Standards Institute.

ANSI. 1982. *American National Standard for Photography (Film and Slides) — Black-and-White Photographic Paper Prints — Practice for Storage.* ANSI PH1.48-1982. New York: American National Standards Institute.

ANSI. 1983. *Determination of Silver in Photographic Films, Papers, Fixing Baths, Sludges, or Residues.* ANSI PH4.42-1983. New York: American National Standards Institute.

ANSI. 1983. *Methods for Determining the Scratch Resistance of Processed Photographic Film.* ANSI PH1.37-1983. New York: American National Standards Institute.

ANSI. 1984. *American National Standard for Photography (Film) — Archival Records, Silver-Gelatin Type, on Cellulose Ester Base.* ANSI PH1.28-1984. New York: American National Standards Institute.

ANSI. 1984. *American National Standard for Photography (Film) — Archival Records, Silver-Gelatin Type, on Polyester Base.* ANSI PH1.41-1984. New York: American National Standards Institute.

ANSI. 1984. *Black-and-White Continuous-Tone Papers — Determination of ISO Speed and Range for Printing.* ANSI ISO 6846-1983. ANSI PH2.2-1984. New York: American National Standards Institute.

ANSI. 1985. *American National Standard for Graphic Arts and Photography — Viewing Conditions — Color Prints, Transparencies and Photomechanical Reproductions.* ANSI Standard PH2.30-1985. New York: American National Standards Institute.

ANSI. 1985. *American National Standard for Photography (Chemicals) — Residual Thiosulfate and Other Chemicals in Films, Plates, and Papers — Determination and Measurement.* ANSI PH4.8-1985. New York: American National Standards Institute.

ANSI. 1985. *American National Standard for Photography (Film) — Processed Safety Film — storage.* ANSI PH1.43-1985. New York: American National Standards Institute.

ANSI. 1986. *American National Standards for Photography (Processing) — Black-and-White Films, Plates, and Papers — Manual Processing Methods.* ANSI PH4.29-1986. New York: American National Standards Institute.

ANSI. 1986. *Methods for Evaluating Processing with Respect to the Stability of the Resultant Image — Black-and-White Papers.* ANSI PH4.32-1986. New York: American National Standards Institute.

ANSI. 1988. *American National Standard for Imaging Media (Film) — Silver-Gelatin Type — Specifications for Stability.* ANSI IT9.1-1988. New York: American National Standards Institute.

ANSI. 1988. *Ammonia-Processed Diazo Films — Specifications for Stability.* ANSI IT9.5-1988. New York: American National Standards Institute.

ANSI. 1988. *Photographic Processed Films, Plates, and Papers — Filing Enclosures and Storage Containers.* ANSI IT9.2-1988. New York: American National Standards Institute.

ANSI. 1989. *American National Standard for Graphic Arts and Photography — Color Prints, Transparencies, and Photomechanical Reproductions — Viewing Conditions.* ANSI PH2.30-1989. New York: American National Standards Institute.

Antonacci, J. 1979. *The Repair of Broken Glass Plates*. Project report, Picture Conservation Division, Public Archives of Canada.

Archer, F.S. 1851. On the Use of Collodion in Photography. *Chemist* **2**: 257-258.

Arnold, H.J.P. 1977. *William Henry Fox Talbot, Pioneer of Photography and Man of Science*. London: Hutchinson Benham.

Asloglou, E. 1938, Sept.-Oct. Selenium Toning Methods for Prints. *British Journal of Photography*, 599-600, 612-613, 629-630, 643-644, 662-663.

Atkins, A. 1843-1853. *British Algae: Cyanotype Impressions*. 3 vols. Halstead Place, England: Privately Published.

Avedon, D. 1972. Standards: Microfilm Permanence and Archival Quality. *Journal of Micrographics* **6**(2): 93-94.

Avedon, D. 1978. Archival Quality and Permanence of Microfilm. *I.M.C. Journal* **1**(2): 12-14.

Avedon, D. 1978. Micrographic Standards Worldwide. *I.M.C. Journal* **1**(3): 11-16.

Bachrach, D. 1888. Chloride of Gold: How to Make It - Its Uses in Photography. *Photographic Mosaics*, 43-46.

Baeckstroem, H., and A. Bostroem. 1936, Dec. The Influence of the Bleaching Bath on the Colour Obtained in the Indirect Sulphide-Toning Process. *Photographic Journal* (London), 607-612

Ball, Cynthia. 1989. *Flattening of Works on Paper*. Research project, Degree Requirement Masters of Art Conservation. Kingston. Queen's University.

Bard, C.C., et al. 1980. Predicting Long-Term Dark Storage Dye Stability Characteristics of Color Photographic Products from Short-Term Tests. *Journal of Applied Photographic Engineering* **6**(2): 42-45.

Barger, M. Susan, et al. 1982. The Cleaning of Daguerreotypes: 1. Physical Sputter Cleaning, A New Technique. In *American Institute for Conservation of Historic and Artistic Works Preprints of Papers Presented at the Tenth Annual Meeting, Milwaukee, Wisconsin, 26-30 May, 1982,* 9-20 Washington, D.C.: AIC.

Barger, M. Susan, et al. 1986. Cleaning Daguerreotypes. *Studies in Conservation* **31**(1): 15-28.

Barron, A. 1974. The Recognition of Early Photographic Processes, Their Care and Conservation. *British Journal of Photography* 121: 14.

Bennett, Colin N. [1935] 1973. Elements of Photogravure. 2nd ed. [London: Technical Press]. Reprinted in Bunnell, Peter. *Nonsilver Printing Processes*. New York: Arno Press.

Bernard, Bruce. 1980. *Photodiscovery. Masterworks of Photography 1840-1940, with Notes on the Photographic Processes by Valerie Lloyd*. New York: Harry N. Abrams.

Bisbee, A. 1973. *The History and Practice of Daguerreotyping*. Reprint. New York: Arno Press.

Blaney, Henry R. 1895. *Photogravure.* New York: Scovill.

Bohem, H. 1975. A Seam-free Envelope for Archival Storage of Photographic Negatives. *American Archivist* 38(3): 403-405.

Boni, A. 1962. *Photographic Literature.* 2 vols. New York: Morgan & Morgan.

Bookstaber, Dennis. 1975. The Ambrotype. *Camera* 35: 34-35.

Borcoman, James. 1976. *Charles Nègre.* Ottawa: The National Gallery of Canada.

Boston. Museum of Fine Arts Dept. of Prints. 1892. *Exhibition Illustrating the Technical Methods of the Reproductive Arts from the XV. Century to the Present Time.* Boston: A. Mudge & Sons.

Bower, P., and C. Brandt. 1981. Operation Paper Lift. *Archivaria* 12: 135-144.

Brettell, Richard, et al. 1984. The Calotype as Print Medium. In *Paper and Light: The Calotype in France and Great Britain, 1839-1870,* 47-63. Boston: David Godine.

Brewster, Sir David. [1856] 1971. *The Stereoscope, Its History, Theory and Construction.* Reprint. Hastings-on-Hudson, N.Y.: Morgan & Morgan.

Brothers, A. 1892. *Photography: Its History, Processes, Apparatus, and Materials.* London: Charles Griffin.

Brown, George E. 1899. *Ferric and Heliographic Processes.* London: Dawborn & Ward.

Brown, Margaret R. 1982. *Boxes for the Protection of Rare Books: Their Design and Construction.* National Preservation Office Publication. Washington, D.C.: Library of Congress.

Bruce, David. 1973. *Sun Pictures, the Hill-Adamson Calotypes.* Greenwich, C.T.: New York Graphic Society.

BSI. 1975. *Recommendations for the Processing and Storage of Silver-gelatin-type Microfilm.* BS 1153. London: British Standards Institution.

BSI. 1979. *Recommendations for the Storage and Exhibition of Archival Documents.* BS 5454. London: British Standards Institution.

BSI. 1979. *Recommendations for Storage Conditions for Silver Image Photographic Plates for Record Purposes.* BS 5687. London: British Standards Institution.

Buchanan, S. 1980. Disaster Prevention and Action. *Oklahoma Librarian* 30(4): 35-41.

Buckland, Gail. 1980. *Fox Talbot and the Invention of Photography.* Boston: David Godine.

Buerger, Janet E. 1982. *The Era of the French Calotype.* Rochester, N.Y.: International Museum of Photography at George Eastman House.

Bunnell, Peter C. 1973. *The Collodion Process and the Ferrotype: Three Accounts.* New York: Arno Press.

Bunnell, Peter C. 1973. *Nonsilver Printing Processes.* New York: Arno Press.

Burbank, W. H. [1891] 1973. *Photographic Printing Methods.* 3rd ed. Reprint. New York: Arno Press.

Burgess, Helen D. 1982. The Bleaching Efficiency and Colour Reversion of Three Borohydride Derivatives. In *American Institute for Conservation of Historical and Artistic Works Preprints of Papers Presented at the Tenth Annual Meeting, Milwaukee, Wisconsin, 26-30 May, 1982*, 40-48. Washington, D.C.: AIC.

Burgess, Helen, and Season Tse. 1987. *The Use of Enzymes in Paper Conservation*. Paper presented at the A.I.C. Annual Conference. Vancouver. May 20-24.

Burgess, N.G. 1856. *The Ambrotype Manual*. New York: D. Burgess.

Burgess, N.G. 1861. *The Photography and Ambrotype Manual*. New York: Hubbard, Burgess.

Burnett, C.J. 1859. Silver Printing Processes. *Photographic Journal* (London) **6**(92): 90; **6**(93): 106-107; **6**(97): 161-162; and **6**(99): 185-186.

Burton, W.K. 1887. *Practical Guide to Photographic and Photomechanical Printing*. London: Marion & Co.

CSA. 1982. *Photography — Practice for the Storage of Processed Safety Photographic Film*. CAN 3-Z7.2.7-M82. Rexdale, Ont.: Canadian Standards Association.

Calhoun, J.M. 1944. The Physical Properties and Dimensional Behaviour of Motion Picture Film. *Journal of the Society of Motion Picture Engineering* **43** (4): 227-266.

Calhoun, J.M. 1952. Cold Storage of Photographic Film. *Photographic Society of America Journal* **18B**(3): 1-4.

Calhoun, J.M. 1953. Storage of Nitrate Amateur Still-Camera Film Negatives. *Journal of the Biological Photographic Association* **21**(3): 1-13.

Calmes, A. 1983-1984. *Preservation Priorities for Textual (Paper) Records at the United States National Archives*. Unpublished report. Washington, D.C.: National Archives and Records Service.

Canadian Government Specification Board. Committee on Graphic Arts Terminology (Photography). 1972. *Glossary of Photographic Terms in General Use in the Graphic Arts*. Canadian Government Specifications Board, No. 94-GP-1. Ottawa: Canada, Dept. of Supply and Services.

Capstaff, J.G., and M.W. Seymour. 1927. Duplication of Motion Picture Negatives. *Transactions of the Society of Motion Picture Engineers* **10**(28): 223-229.

Carroll, B.H. 1980. *Introduction to Photographic Theory: The Silver Halide Process*. New York: John Wiley & Sons.

Carroll, J.F., and J. M. Calhoun. 1955. Effects of Nitrogen Oxide Gases on Processed Acetate Film. *Journal of the Society of Motion Picture and Television Engineers* **64**: 501-507.

Carroll, J.F., and J.O. Paul. 1961. Test Methods for Rating Abrasion Resistance of Photographic Film. *Photographic Science and Engineering* **5**(5): 288-296.

Carroll, J.S. 1976. *Photographic Facts and Formulas*. Rev. ed. of original by E.J. Wall and F.I. Jordan. Englewood Cliffs, N.J.: Prentice-Hall.

Carroll, J.S. 1977. Photographic Papers: Descriptions and Applications. In *Photographic Lab Handbook*. 4th ed., 142-174. Englewood Cliffs, N.J.: Prentice-Hall.

Carroll, J.S. 1979. *Photographic Lab Handbook*. 5th ed. Garden City, N.Y.: Amphoto.

Cartier-Bresson, A., et al. 1984. Étude experimentale de la détérioration et de la restauration chimique des épreuves photographiques sur papier sale [Experimental Study of the Deterioration and Chemical Restoration of Salted Paper Prints]. In *ICOM Committee for Conservation Preprints*, 84.14.16-84.14.21. Paris: ICOM.

Cartwright, H. Mills. 1939. *Photogravure*. Boston: The American Photographic Publishing Co.

Chayt, Steven. 1983. *Collotype: Being a History, Practicum, Bibliography*. Winter Haven, F.L.: Anachronic Editions.

Clapp, A. F. 1978. *Curatorial Care of Works of Art on Paper*. Oberlin, O.H.: Intermuseum Conservation Association.

Clark, Lyonel. 1890. *Platinum Toning*. New York: E. and H. T. Anthony Co.

Clerc, Louis-Philippe. 1930. *Photography: Theory and Practice*. London: Isaac Pitman & Sons.

Coe, Brian. 1976. *The Birth of Photography: The Story of the Formative Years, 1800-1900*. London: Ash & Grant Ltd.

Coe, Brian. 1977. Making Calotype Paper and Prints. *Photographic Journal* (London), Nov.-Dec., 281-283.

Coe, Brian. 1977. Sun Pictures: Printing Talbot's Calotype Negatives. *History of Photography* 1(3): 175-182.

Coe, Brian. 1978. *Colour Photography: The First Hundred Years, 1840-1940*. London: Ash & Grant.

Coe, Brian, and Mark Haworth-Booth. 1983. *A Guide to Early Photographic Processes*. London: Victoria and Albert Museum and Hurtwood Press.

Colton, E.K., and E.J. Wiegand. 1950. Moisture in Photographic Film and Its Measurement. *Photographic Science and Engineering* 2(3): 170-176.

Constable, W.G. 1934. Appendix III: Framing and the Control of Humidity. In *Some Notes on Atmospheric Humidity in Relation to Works of Art*, 39-42. London: Courtauld Institute of Art.

Cook, M.M., and J.A. Lander. 1979. Use of Sodium Borohydride to Control Heavy Metal Discharge in the Photographic Industry. *Journal of Applied Photographic Engineering* 5(3): 144-147.

Cooney, J.D., and D.M. Wiles. 1981. *Proposed Standard Specifications for Electrophotographic Film for Archival Records, Organic Photoconductor Type, on Polyester Base*. Special Report. Ottawa: National Research Council.

Coote, J. H. 1970. *Photofinishing Techniques and Equipment.* London: Focal Press.

Corbeil, Marie-Claude. 1989. *Detection of Silver in Painted Photograph Samples.* Canadian Conservation Institute Analytical Report ARS, no. 2766. Ottawa: CCI.

Couprie, S., et al. 1970. Increase of Density of the Silver Image During Storage After Processing. *Journal of Photographic Science* **18**: 159-160.

Crabtree, A.D. 1971. A Guide to the Principles of Making Duplicate Negatives. *British Journal of Photography* **118**: pages unknown.

Crabtree, J.I. 1930. D. and P. Practice. *British Journal of Photography,* Aug.-Sept., 487-489, 506-508, 521-524, 535-537, 552-554, 572-574.

Crabtree, J.I., and C.H. Schwingel. 1932. The Duplication of Motion Picture Negatives. *Journal of the Society of Motion Picture Engineers* **19**: 891-908.

Crabtree, J.I., et al. 1940. The Elimination of Hypo from Photographic Images. *Journal of the Franklin Institute* **230**(1380): 701-725.

Crabtree, J.I., et al. 1943. The Removal of Hypo and Silver Salts from Photographic Material as Affected by the Composition of the Processing Solutions. *Journal of the Society of Motion Picture Engineers* **41**: 9-68.

Craddock, A.B. 1984. *Control of Temperature and Humidity in Small Institutions.*.New York State Conservation Consultancy Bulletin.

Crawford, William. 1979. *The Keepers of Light.* Dobbs Ferry, N.Y.: Morgan & Morgan.

Crookes, William. 1855. On Wax and Waxing Paper. *Journal of the Photographic Society* **2**(34): 231-232.

Crookes, William. 1857. The Albumen Process on Collodion. *Journal of the Photographic Society* (London) **3**(55): 298-304.

Croy, O.R. 1964. *Camera Copying and Reproduction.* Trans. L. A. Mannheim. New York: Focal Press.

Cummings, J.W., et al. 1950. Spontaneous Ignition of Decomposing Cellulose Nitrate Film. *Journal of the Society of Motion Picture Engineers* **54**(3): 268-274.

Cundall, George. 1844. The Practice of the Calotype Process of Photography. *The London, Edinburgh and Dublin Philosophical Magazine and Journal of Science,* 3rd series, **24**(160): 321-332.

Current, I.B. 1954. Equipment for Testing Some Physical Characteristics of Sensitized Materials. *Photographic Engineering* **5**(4): 227-233.

Daguerre, Louis Jacques Mandé. 1839. Practical Description of the Process Called the Daguerreotype. Trans. J.F. Frazer. *Journal of the Franklin Institute,* n.s. **24**: 303-311.

Daguerre, Louis Jacques Mandé [1839] 1971. *Historique et description des procédés du daguerréotype et du diorama. [An Historical and Descriptive Account of the Various Processes of the Daguerreotype and the Diorama.]* [Paris: Susse Frères] Reprint, with introduction by Beaumont Newhall. New York: Winter House.

Daniels, V., et al. 1979. Gas Plasma Reactions for the Conservation of Antiquities. *Studies in Conservation* 24(2): 85-92.

Daniels, V. 1981. Plasma Reduction of Silver Tarnish on Daguerreotypes. *Studies in Conservation* 26(2): 45-49.

Darrah, William Culp. 1964. *Cartes de Visite in 19th Century Photography.* Gettysburg, P.A.: Privately published.

Darrah, William Culp. 1981. *Stereo Views: A History of Stereographs in America and Their Collection.* Gettysburg, P.A.: Times and News Publishing Co.

Davanne, A. 1875. Formulary. *Photographic Mosaics,* 75-80.

Davies, L.A., and J.R. Tueller. 1981. Book Drying in a Space Chamber. In *Disasters, Prevention and Coping: Proceedings of the Conference May 21-22, 1980,* App. 2, 123-142. Stanford, C.A.: Stanford University Libraries.

Davis, Ralph A. 1978. Bromoil Printing. *Photographic Society of America Journal* 44(3): 20-26.

Dawson, George. 1880. The Platinotype Printing Process. *British Journal of Photography* 27(1029): 399-400.

Deane, Robert. 1981. *A Bibliography of Photographic Processes, Their Conservation and Storage,* no. 1. Canberra: Australian National Gallery.

Delamotte, P.H., et al. 1855. First Report of the Committee Appointed to Take Into Consideration the Question of the Fading of Positive Photographic Pictures Upon Paper. *Journal of the Photographic Society* (London) 2(36): 251-252.

Denison, Herbert. [1895] 1974. *A Treatise on Photogravure.* [London: Iliffe & Sons] Reprint. Rochester, N.Y.: Visual Studies Workshop Press.

Denstman, H. 1973. Copy Negatives: Original Quality. *Industrial Photography* 22(11): 22-25.

Denstman, H. 1977. Illumination for Copying: It's What's in Back That Counts. *Industrial Photography* 26(2): 29-32.

Denstman, H. 1978. Polarized Light for High Fidelity Reproduction. *Industrial Photography* 27(10): 23-25, 60.

Derkacy, D., and D. Jones. 1975. The Carbro Process. *Petersen's PhotoGraphic Magazine,* July, 71-74.

DeSantis, Pia C. 1983. Some Observations on the Use of Enzymes in Paper Conservation. *Journal of the American Institute for Conservation* 23(1): 7-27.

Deschin, J. 1979. Mass Produced in the 19th Century for Pennies a Piece, Tintypes are Still a Collector's Bargain. *Popular Photography,* Dec., 66, 170.

Dickson, Edward R., ed. 1913-1916. *Platinum Print. A Journal of Personal Expression.* New York: Edward R. Dickson and Charles H. Barnard.

Dinaburg, M.S. 1967. *Photosensitive Diazo Compounds.* London: Focal Press.

Dobrusskin, Sebastian. 1989. *Identification, Conservation and Restoration of Colored and Overpainted Photographs*. Project report, Picture Conservation Division, National Archives of Canada.

Dorfman, H. 1976. Film Preservation. *Microfilm Techniques* 5(6): 7, 10, 12, 21.

Dorfman, H. 1978. The Effect of Fungus on Silver Gelatin, Diazo and Vesicular Films. *Journal of Micrographics* **11**(4): 257-260.

Down, Jane. 1988. *Report on Adhesive Testing at the Canadian Conservation Institute*. Paper presented at Symposium '88, Canadian Conservation Institute, held at the National Gallery of Canada, September 1988.

Drago, F.J., and W.E. Lee. 1984. Stability and Restoration of Images on Kodak Professional B/W Duplicating Film/4168. *Journal of Imaging Technology* **10**(3): 113-118.

Duchochois, P.C. 1892. *Photographic Reproduction Processes*. London: Hampton, Judd.

Dunn, Carlton E. 1940. *Natural Color Processes*. 3rd ed. Boston: American Photographic Publishing Co.

Eastman Kodak. n.d. *Using Polarized Light for Copying*. Kodak Publication no. S-70-1-2. Kodak AV Equipment Memo. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1951. *Kodak Reference Handbook: Materials, Processes, Techniques*. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1952. *Stains on Negatives and Prints*. Kodak Photographic Notebook, no. J-18, Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1973. *International Glossary of Photographic Terms*. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1973. *Processing Chemicals and Formulae for Black-and-White Photography*. Kodak Publication, no. J-1. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1974. *Kodak Darkroom Dataguide for Black-and-White*. 5th ed. Kodak Publication, no. R-20. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1977. *Photography with Large Format Cameras*. Kodak Publication, no. O-18. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1978. *Kodak B/W Photographic Papers*. Kodak Publication, no. G-1. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1978. *Printing Color Negatives*. Kodak Publication, no. E-66. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1979. Sensitized Products: Ambrotypes. *Tips* (Rochester, N.Y.) **10**(5): 10.

Eastman Kodak. 1982. Dye Stability: Kodak Scientists Discuss Practical and Theoretical Duration. *Professional Photographer* **109**(2038): 22-26.

Eastman Kodak. 1982. Salvaging Black-and-White Photographic Images: Transferring a Black-and-

White Emulsion Layer from Nitrate or Early Safety-Base Films to a New Support. *Current Information Summary* (Rochester, N.Y.) **12**: 1-2.

Eastman Kodak. 1983. *Storage and Preservation of Microfilms*. Kodak Publication, no. D-31. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1984. *Black-and-White Film and Paper Processing and Process Monitoring*. Kodak Publication, no. Z-128. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1984. *Copying and Duplicating in Black-and-White and Color*. Kodak Publication, no. M-1. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1985. *Black-and-White Processing Using Kodak Chemicals*. Kodak Publication, no. J-1. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1985. *Quality Enlarging with Kodak B/W Papers*. Kodak Publication, no. G-1. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1985. *Practical Densitometry*. Kodak Publication, no. E-59. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1985. *Conservation of Photographs*. Kodak Publication, no. F-40. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1987. *Kodak Professional Black-and-White Films*. Kodak Publication, no. F-5. Rochester, N.Y.: Eastman Kodak Co.

Eastman Kodak. 1987. *Paper Information from Kodak: Kodak Ektacolor Plus and Professional Papers for the Professional Finisher*. Kodak Publication, no. E-18. Rochester, N.Y.: Eastman Kodak Co.

Eaton, G.T. 1970. Preservation, Deterioration, Restoration of Photographic Images. *Library Quarterly* **40**(1): 85-98.

Eaton, G.T. 1987. History of Processing and Image Stability. In *Pioneers of Photography: Their Achievements in Science and Technology*. Eugene Ostroff, ed., 87-93. Springfield, V.A.: SPSE.

Eaton, G.T., and J.I. Crabtree. 1943. Washing Photographic Films and Prints in Sea Water. *Journal of the Society of Motion Picture Engineers* **40**: 380-391.

Eder, Joseph Maria. 1929. *Lichtspausverfahren, die Platinotypie und verschiedene kopierverfahr ohne silbersalze*. Halle: Wilhelm Knapp.

Eder, Josef-Maria. [1945, 1972] 1978. *The History of Photography*. Trans. by Edward Epstean. [New York: Columbia University Press]. Reprint. 4th ed. New York: Dover.

Enyeart, J. 1970. Reviving a Daguerreotype. *Photographic Journal* (London), Sept., 338-344.

Epstean, E., and J. Tennant. 1934. Daguerreotype in Europe and the United States, 1839-1853. *Photo-Engravers Bulletin*, Nov., 262-274.

Estabrooke, Edward M. 1878. Practical Ferrotype Process. *The Photographic Rays of Light* **1**(1): 12-13.

Estabrooke, Edward. [1873] 1972. *The Ferrotype and How to Make It*. [Cincinnati, Ohio: Gatchel & Hyatt]. Reprint. Hastings-on-Hudson, N.Y.: Morgan & Morgan.

Evans, Frederick. 1908. Some Notes on Platinum Printing. *Amateur Photographer* (London), Sept. 8.

Fassitt, F.T. 1862. A Few Words in Favour of an Old Friend: The Salt Process. *American Journal of Photography and Allied Arts and Sciences* (New York) 6(1): 12-16.

Feldman, L.H. 1981. Discoloration of Black-and-White Photographic Prints. *Journal of Applied Photographic Engineering* 7(1): 1-9.

Field, Ruth K. n.d. *The Missouri Historical Society's Method for the Restoration of Daguerreotypes.* Unpublished manual. n.p.

Fisher, C. n.d. Fehlererscheinungen in der Positiv-Abteilung. *Photographische Industrie* **30**: 734-736.

Fischer, D.J., and T.W. Duncan. 1975. Conservation Research: Flood-Damaged Library Materials. *Bulletin of the American Institute for Conservation* **15** (2): 27-47.

Fisher-Taylor, G. 1979. Care and Processing of Archival Black-and-White Prints. *Printletter 19* **4**(1): 16-17.

Fleming, William D. 1938. Home Manufacture of Materials for Carbon Printing. *American Photography* **32**(8): 570, 572-576.

Fraprie, Frank R., and Walter Woodbury. 1931. *Photographic Amusements.* Boston: American Photographic Publishing Co.

Friedman, J. S. 1968. *History of Colour Photography.* New York: Focal Press.

Fuji Photo Film. 1989. *Fuji Film Data Sheet: Fujicolor Paper Super FA.* Publication AF-3-615E. Tokyo: Fuji Photo Film Co. Ltd.

Furlonge, F. Holland. 1856. On the Calotype Process. *Photographic Notes* **1**(1): 5.

Garwood, A.J. 1907. The Intensification and Reduction of Gelatine Negatives. *American Photography* **1**: 17-25.

Gassan, Arnold. 1974. *Handbook for Contemporary Photography.* Athens, O.H.: Handbook Co.

Gear, J.L., et al. 1977. Film Recovery of Some Deteriorated Black and White Negatives. *American Archivist* **40**(3): 363-368.

Gernsheim, Helmut. 1959. *The Origins of Photography.* London: Thames and Hudson.

Gernsheim, Helmut. 1969. Talbot and Herschel's Photographic Experiments 1839. *Image* **8**(3): 132-137.

Gernsheim, Helmut and Alison. 1968. *L.J.M. Daguerre: The History of the Diorama and the Daguerreotype.* Reprint. New York: Dover.

Gernsheim, Helmut and Alison. 1969. *The History of Photography: from the Camera Obscura to the Beginning of the Modern Era.* New York: McGraw-Hill.

Gill, Arthur T. 1974. *The Daguerreotype.* Paper presented at The Recognition of Early Photographic Processes, Their Care and Conservation: A Royal Photographic Society Symposium, London.

Gill, Arthur T. 1974. The Rise and Fall of the Daguerreotype. *Photographic Journal* (London) **114** (3): 129-131.

Gill, Arthur T. 1978. *Photographic Processes: A Glossary and a Chart for Recognition.* Museums Association Information Sheet, no. 21. London: Museums Association.

Gill, Arthur T. 1978. Recognition of Photographic Processes. *History of Photography* **2**(1): 34-36.

Gill, Arthur T. 1980. Nicholas Henneman 1813-1893. *History of Photography: An International Quarterly* **4**(4): 313-322.

Gillet, M., et al. 1981. Influence de l'environnement sur la conservation des documents photographiques modernes [Environmental Influence on the Conservation of Modern Photographic Documents]. In *Les documents graphiques et photographiques: analyse et conservation*, 39-109. Paris: Édition du Centre National de la Recherche Scientifique.

Gillet, M., et al. 1986. Glass Plate Negatives: Preservation and Restoration. *Restaurator.* vol. 7 no. 2: 49-80.

Gladstone, J.S. 1892. Fugacity of Bromide Prints. *British Journal of Photography,* July 29, 484.

Goodman, Devara. 1976. *Instruction and Troubleshooting Guide for Platinum and Palladium Photoprinting.* Wilmington, D.E.: Elegant Images.

Gould, Barbara. 1987. The Removal of Secondary Supports from Works of Art on Paper. *The Book and Paper Group Annual.* **6**: Washington: A.I.C.: 52-64.

Green, A., and G.I.P. Levenson. 1972. A Practical Swellmeter. *Journal of Photographic Science* **20**: 205-210.

Green, Robert. 1975. *Carbro, Carbon.* 2nd ed., rev. Fort Wayne, I.N.: Gallery 614.

Green, Robert. 1977. Tri-Color Carbro. *Petersen's PhotoGraphic Magazine,* May, 78-87.

Grigsby, W.D. 1977. *Photographic Restoration: A Compilation of Information and References.* Term paper. Ryerson Polytechnical Institute, Toronto.

Grossman, J. 1980. Emulsion Stripping: The Bare Facts. *Industrial Photography* **29**(1): 22-23.

Hafey, John, and Tom Shillea. 1979. *The Platinum Print.* Rochester, N.Y.: Graphic Arts Research Center.

Haist, Grant. 1979. *Modern Photographic Processing.* 2 vols. New York: John Wiley & Sons.

Haney, F.J. 1978. Illuminating Your Copyboard Mathematically: A System to Measure Light Distribution Pattern. *Industrial Photography* **27**(5): 26-27.

Hannaford, Michael. 1959. Iron Printing Process. *Photographic Journal* (London) **6**: 36.

Hannavy, J. 1978. The Magnificent Ambrotypes. *British Journal of Photography* **123**(8): 153-155.

Hardwich, Thomas F. 1860. On Collodion for the Dry Processes. *American Journal of Photography and the Allied Arts and Sciences* (New York) **2**(21): 331-336; and **2**(22): 342-345.

Hawkins, G. L. 1933. *Pigment Printing*. London: Henry Greenwood & Co.

Haynes, R. 1981. Emergency Storage for Nitrate Film: Conservation Tips. *History News* 36(1): 38-41.

Haynes, R. 1988. A Cold Storage Emergency Procedure for Still Camera Negatives Made with Cellulose Nitrate. *MASCA Journal* 1(5): 146-148.

Heidke, R.L., et al. 1985. Evolution of Kodak Photographic Color Negative Print Papers. *Journal of Imaging Technology* 11(3): 93-97.

Heighway, W. 1879. The Ferrotype. *Practical Photographer* 3(7): 686-688.

Hendriks, Klaus B. 1978. *Procedures for the Inspection of Processed Silver Gelatin Microfilm for Redox Blemishes*. Ottawa: Public Archives of Canada.

Hendriks, Klaus B. 1984. *The Preservation and Restoration of Photographic Materials in Archives and Libraries: A RAMP Study With Guidelines*. Paris: Records and Archives Management Program, UNESCO.

Hendriks, Klaus B. 1985. Experiments on the Restoration of Discoloured Black-and-White Photographs in Chemical Solutions. *SPSE Second International Symposium, The Stability and Preservation of Photographic Images: Printing of Transcript Summaries*, 148-163. Springfield, V.A.: Society of Photographic Scientists and Engineers.

Hendriks, Klaus B. 1987. Notes on Microfilm. *Archivaria* 23: 179-184.

Hendriks, Klaus B. 1988. Über die chemische Restaurierung des Silberbildes vergilbter oder verfärber Photographien [On the Chemical Restoration of Silver Images in Faded or Discolored Photographs]. *Wiener Berichte über Naturwissenschaft in der Kunst* 4/5: 372-389.

Hendriks, Klaus B. 1989. The Stability and Preservation of Recorded Images. In *Imaging Processes and Materials: Neblette's Eighth Edition*, ed. by John Sturge, Vivian Walworth and Allan Shepp, 637-684. New York: Van Nostrand Reinhold.

Hendriks, Klaus B., and B. Lesser. 1983. Disaster Preparedness and Recovery: Photographic Materials. *American Archivist* 46(1): 52-68.

Hendriks, Klaus B., et al. 1984. Experiments on the Restoration of Discoloured Black-and-White Photographs in Chemical Solutions. In *ICOM Committee for Conservation, 7th Triennial Meeting, Copenhagen, 10-14 September, 1984, Preprints*, 2: 84.14.34 - 84.14.37. Paris: International Council of Museums.

Hendriks, Klaus B., et al. 1984. Properties and Stability of Gelatin Layers in Photographic Materials. In *American Institute for Conservation of Historic and Artistic Works Preprints of Papers Presented at the Twelfth Annual Meeting, Los Angeles, California, 15-20 May, 1984*, 52-62. Washington, D.C.: AIC.

Hendriks, Klaus B., and L. Ross. 1988. The Restoration of Discoloured Black-and-White

Photographic Images in Chemical Solutions. *AIC Preprints of Papers Presented at the Sixteenth Annual Meeting, New Orleans, Louisiana, June 1-5, 1988*, 99-117. Washington, D.C.: American Institute for Conservation of Historical and Artistic Works.

Henn, R.W., and J.I. Crabtree. 1947. Sulphide Stain: Its Nature, Cause and Methods of Prevention. *Photographic Society of America Journal* **13**: 752-758.

Henn, R.W., et al. 1951. An Ammonium Hypo Reducer. *Photographic Society of America Journal* **17B** (11): 110-113.

Henn, R.W., et al. 1956. The Effect of Salt Baths on Hypo and Silver Elimination. *Photographic Engineering* **7**(3 and 4): 153-164.

Henn, R.W., and I.A. Olivares. 1960. Tropical Storage of Processed Negatives. *Photographic Science and Engineering* **4**(4): 229-233.

Henn, R.W., and D.G. Wiest. 1963. Microscopic Spots in Processed Microfilm: Their Nature and Prevention. *Photographic Science and Engineering* **7** (5): 253-261.

Henn, R.W., Wiest, D.G., and Mack, B. 1965. Microscopic Spots in Processed Microfilm: The Effect of Iodide. *Photographic Science and Engineering* 9(3): 167-173.

Hepworth, T. [1894] 1978. *The Book of the Lantern: A Practical Guide to the Working of the Optical (or Magic) Lantern, With Full and Precise Directions for Making and Colouring Lantern Pictures*. [5th ed. London: Hazell, Watson, and Viney, Ltd.,]. Reprint. 6th ed. New York: Arno Press.

Herschel, Sir John F.W. 1842. On the Action of the Rays of the Solar Spectrum on Vegetable Colours, and on Some New Photographic Processes. *Philosophical Transactions* **132**(1): 181-214.

Hickman, M.J. 1970. *Measurement of Humidity*. 4th ed. Notes on Applied Science, no. 4. London: Natural Physics Laboratory.

Hill, Levi L. [1856] 1972. *A Treatise on Heliochromy*. Privately published, [Westkill, N.Y.: Privately published]. Facsimile ed. with introduction by William B. Becker. State College, P.A.: Carnation Press.

Hinton, A. Horsley. 1902. Platinotype Printing. *Barnet Book of Photography*. 6th ed., 197-224. London: Elliott & Sons.

Hornsby, K.M. 1958. Reducers and Intensifiers with a Modern Negative Material. *British Journal of Photography* **105**: 42-46.

Horvath, D. 1981. Archival Appraisal of Photographic Materials. *Picturescope* **29**(2): 44-47.

Hubbell, D.C., et al. 1967. Methods for Testing Image Stability of Color Photographic Products. *Photographic Science and Engineering* **2**(5): 295-305.

Hunt, Robert. 1853. *A Manual of Photography*. 3rd ed. London: J.J. Griffin.

Hunt, Robert. [1841] 1973. *Popular Treatise on the Art of Photography*. [London]. Reprint. Athens, O.H.: Ohio University Press.

Hunt, Robert. [1854] 1973. *Researches on Light*. [London: Longman, Brown, Green, and Longman]. Reprint. New York: Arno Press.

Hunt, R.W.G. 1975. Reflection Prints in Colour. In *The Reproduction of Colour*. 3rd ed., by R.W.G. Hunt, 208-221. Kings Langley, Herts.: Fountain Press.

Ilford, Ltd. 1979. *Ilfobrom Galerie*. Brochure, no. ILP-7905. Paramus, N.J.: Ilford Ltd.

Ilford. 1988. *Mounting and Laminating: Cibachrome Display Print Materials and Films*. Paramus, N.J.: Ilford Photo Corporation.

Imax, C.L. 1920. Durable Sensitive Albumen Paper. *St. Louis and Canadian Photographer* 8(8): 303.

Inglis, James. 1880. Inglis Extra Rapid Process. *Practical Photographer* 4(4): 60.

International Museum of Photography. 1982. *Color as Form: A History of Color Photography*. Rochester, N.Y: International Museum of Photography at George Eastman House.

ISO. 1974. *Photography — Silver-Gelatin Type Microfilms — Processing and Storage for Archival Purposes*. ISO 2803-1974(E). Geneva: International Organization for Standardization.

ISO. 1976. *Photography — Silver Image Photographic Plates for Record Purposes — Storage Conditions*. ISO 3897-1976(E). Geneva: International Organization of Standardization.

ISO. 1980. *Photography — Practice for the Storage of Processed Safety Photographic Film*. ISO 5466-1980(E). Geneva: International Organization of Standardization.

ISO. 1980. *Photography — Silver Image Photographic Paper Prints for Record Purposes — Storage Conditions*. ISO 6051-1980. Geneva: International Organization of Standardization.

Ives, C.I., and E. Huse. 1928. Notes on Making Duplicate Negatives. *Transactions of the Society of Motion Picture Engineers* 12: 382-389.

Ives, C.I., and J.I. Crabtree. 1937. Two New Films for Duplicating Work. *Journal of the Society of Motion Picture Engineers* 29: 317-325.

Jacobson, Ralph C. 1978. *The Manual of Photography*. London: Focal Press Ltd.

James, T. H., ed. 1977. *The Theory of the Photographic Process*. 4th ed. New York: Macmillan.

James, T.H., and G.C. Higgins. 1968. *The Fundamentals of Photographic Theory*. 2nd ed. Dobbs Ferry, N.Y.: Morgan & Morgan.

Jammes, André. 1975. *Hippolyte Bayard: Ein verkannter Erfinder und Meister der Photographie*. Lucerne: C. J. Bucher.

Jammes, André, and Eugenia Parris Janis. 1983. *The Art of the French Calotype with a Critical Dictionary of Photographers, 1845-1870*. Princeton, N.J.: Princeton University Press.

Jammes, Isabelle. 1981. *Blanquart-Evrard et les origines de l'édition photographique française: catalogue raisonné des albums photographiques édités 1851-1855*. Geneva: Droz.

Jane, M. 1862. Dry Collodion: Modified from Several Processes. *American Journal of Photography and the Allied Arts and Sciences* (New York) 4(21): 488-490.

Jenkins, Reese V. 1975. *Images and Enterprise: Technology and the American Photographic Industry*. Baltimore: The Johns Hopkins University Press.

Jerome, A. 1892. *Crayon Portraiture*. New York: Baker & Taylor Co.

Jones, Bernard Edward, ed. [1911] 1974. *Cassell's Encyclopedia of Photography*. [London: Cassell]. Reprint. New York: Arno Press.

Jones, Darryl. 1976. Carbonated Prints, *35mm Photography*. Summer, 72-81, 107-111.

Jussim, Estelle. 1974. *Visual Communication and the Graphic Arts: Photographic Technologies in the Nineteenth Century*. New York: R.R. Bowker.

Karp, C. 1983. Calculating Atmospheric Humidity. *Studies in Conservation* 28(1): 24-28.

Karr, Laurence F., ed. 1980. *Proceedings: Conference on the Cold Storage of Motion Picture Films, April 21-23*. Washington, D.C.: American Film Institute and Library of Congress.

Katcher, Philip. 1978. How to Date an Image From Its Mat. *Photographic Society of America Journal* 44(8): 26.

Keefe, L.E., and D. Inch. 1984. *The Life of a Photograph*. Boston: Focal Press.

Keiley, Joseph T., and Alfred Stieglitz. 1900. Improved Glycerine Process for the Development of Platinum Prints. *Camera Notes*, April, 221-238.

Kennedy, Nora. 1988. Three French Photograph Conservation Techniques. In *Topics in Photographic Preservation*, 2: 40-49. Washington, D.C.: American Institute for Conservation. Photographic Materials Group.

Kernan, Sean. 1977. An Old-Time Technique: Palladium. *35mm Photography*, Spring, 36-40, 111-112.

Keyes, Keiko Mizushima. 1990. Some Practical Methods for the Treatment with Moisture of Moisture-Sensitive Works on Paper. *Symposium '88, Postprints*. Ottawa. Canadian Conservation Institute, to be published in winter '91.

Kopperl, D.F., et al. 1982. A Method to Predict the Effect of Residual Thiosulfate Content on Long-term Image-stability Characteristics of Radiographic Films. *Journal of Applied Photographic Engineering* 8(2): 83-89.

Kopperl, D.F., and C.C. Bard. 1985. Freeze/Thaw Cycling of Motion-Picture Films. *Society of Motion-Picture and Television Engineers Journal* 94(8): 826-827.

Kosar, Jaromir. 1965. *Light-Sensitive Systems: Chemistry and Application of Nonsilver Halide Photographic Processes*. New York: John Wiley & Sons.

Krause, Peter. 1989. Color Photography. In *Imaging Processes and Materials: Neblette's Eighth Edition*, ed. by J.M. Sturge, et al. 181-225. New York: Van Nostrand Reinhold.

Lafontaine, R. 1981. *Environmental Norms for Canadian Museums, Art Galleries and Archives.* Canadian Conservation Institute Technical Bulletin, no. 5. Ottawa: CCI.

Lafontaine, R. 1981. *Recommended Environmental Monitors for Museums, Archives, and Art Galleries.* Canadian Conservation Institute Technical Bulletin, no. 3. Ottawa: CCI.

Langford, Michael J. 1980. *Advanced Photography: A Grammar of Technique*. 4th ed. London: Focal Press Ltd.

Langford, Michael. 1986. *Basic Photography*. 5th ed. London: Focal Press.

Lassam, Robert. 1979. *Fox Talbot: Photographer.* Tisbury, Wiltshire, England: The Compton Press.

Leaper, Clement. 1891. *Materia Photographica.* London: Iliffe & Sons.

Lee, W.E., and E.R. Brown. 1977. The Developing Agents and Their Reactions. In *Theory of the Photographic Process*. 4th ed., ed. by T.H. James, 291-334. New York: Macmillan.

Lee, W.E., et al. 1984. New Procedures for Processing and Storage of Kodak Spectroscopic Plates, Type 111a-J. *Journal of Imaging Technology* **10** (1): 22-26.

Lee, W.E., et al. 1984. Toner Treatments for Photographic Images to Enhance Image Stability. *Journal of Imaging Technology* **10**(3): 119-126.

LeGray, Gustave. 1850. *Traité pratique de photographie sur papier et sur verre*. [Paris, 1850]. Trans. Thomas Cousins. *A Practical Treatise on Photography, upon Paper and Glass*. London: T. and R. Willats.

Lessard, Elizabeth. 1980. *Cyanotypes: A Modern Use for an Old Technique*. American Association for State and Local History. Technical Leaflet, no. 133. Originally published in History News, **35**(12).

Levenson, G.I.P. 1952. Thick or Clear? *Functional Photography* **4**(3): 5-7.

Levenson, G.I.P. 1978. Correspondence on restoration of shrunken sheet film. Sept. 29.

Liesegang, Paul. 1877. On a Convenient Way of Preparing Collodio-chloride. *Photographic World* (Philadelphia) **1**(4): 103-104.

Lietze, Ernst. [1888] 1974. *Modern Heliographic Processes*. [New York: D. Van Nostrand Co.]. Reprint. Rochester, N.Y.: Visual Studies Workshop.

Lilien, Otto M. 1972. *History of Industrial Gravure Printing up to 1900*. London: Lund Humphries.

Lind, E. 1938. Some Hints on the Person Printing Method. *British Journal of Photography* **85**: 214-215.

Lloyd, Valerie. 1976. *Photography: The First Eighty Years*. London: P&D Colnaghi.

Lothrop, E.S. Jr. 1973. The Old Ways Dead? Not on Your Tintype! *Popular Photography* **36**: 111-112.

Luckey, W., et al. 1955. The Effects of Various Pre-treatments on the Reaction of Hydrogen Peroxide with a Silver Image. *Photographic Society of America Technical Quarterly* 2(4): 133-134.

Lull, W.P., and L.E. Merk. 1982. Lighting for Storage of Museum Collections: Developing a System for Safekeeping of Light-sensitive Materials. *Technology and Conservation* 7(2): 20-25.

Lyte, F. Maxwell. 1954. Instantaneous Collodion Process. *Journal of the Photographic Society* (London) 2(22): 30.

M.D. 1859. Modification of the Waxed Paper Process. *Photographic Journal* (London) 6(99): 186-188.

MacIntyre, J.A. 1934. Air Conditioning for Mantegna's Cartoons at Hampton Court Palace. *Technical Studies in the Field of the Fine Arts* 2(4): 171-184.

Mackison, Frank W. ed. 1978. *NIOSH/OSHA Pocket Guide to Chemical Hazards*. Cincinatti, O.H.: National Institute for Occupational Safety and Health.

Mannheim, L.A., and Viscount Hanworth. 1979. *D.A. Spencer's Colour Photography in Practice*. See Spencer, D.A. 1979.

Marton, A. M. 1905. *A New Treatise on the Modern Methods of Carbon Printing*. Bloomington, Il.: Pantagraph Printing & Stationery Co.

Maskell, Alfred, and Robert Demachy. [1878] 1973. *The Photo-Aquatint, or the Gum-Bichromate Process.* 2nd ed. [London: Hazell, Watson & Viney]. Reprinted in Bunnell, Peter. Nonsilver Printing Processes. New York: Arno Press.

Mason, L.F.A., et al. 1981. Processing Black-and-White Prints on Paper Base for Permanence. *Journal of Applied Photographic Engineering* 7(2): 64-66.

Mathey, R.G., et al. 1983. *Air Quality Criteria for Storage of Paper-based Archival Records.* NBSIR, nos. 83-2767 and 83-2770. Washington, D.C.: National Bureau of Standards, National Archives and Record Service.

Mattey, D.A., and R.W. Henn. 1966. Determination of Thiosulfate and Thionates in Film with Silver Nitrate. *Photographic Science and Engineering* 10(4): 202-208.

Mayall, J.E. 1859. A New Collodion for Field Work. *Photographic Journal* (London) 6(94): 118-119.

McCamy, C.S., and C.I. Pope. 1970. Redox Blemishes — Their Cause and Prevention. *Journal of Micrographics* 3(4): 165-170.

McCann, Michael. 1975. *Solvents Used in Conservation: Health Hazards Manual for Artists.* N.Y.: Foundation for the Community of Artists.

McCann, Michael. 1979. *Artists Beware!* New York: Watson Guptill.

MacLeod, K.J. 1978. *Museum Lighting*. Canadian Conservation Institute Technical Bulletin, no. 2. Ottawa: CCI.

MacLeod, K.J. 1978. *Relative Humidity: Its Importance, Measurement and Control in Museums.* Canadian Conservation Institute Technical Bulletin, no. 1. Ottawa: CCI.

Mees, C.E. Kenneth. 1961. *From Dry Plates to Ektachrome Film: A Story of Photographic Research.* New York: Ziff-Davis Publishing Co.

Michalski, Stephen. 1987. *Display Cases.* Draft version of a Canadian Conservation Institute Technical Bulletin, in preparation.

Minogue, A.F. 1946. Treatment of Fire and Water Damaged Records. *American Archivist* **9**(1): 17-25.

Moffat, Elizabeth and Laver, Marilyn. 1981. *Erasers and Related Dry Cleaning Materials.* Canadian Conservation Institute Analytical Report ARS, no. 1738.

Moor, Ian. 1976-1977. The Ambrotype: Research Into Its Restoration and Conservation. *Paper Conservator* **1**: 22-25 and **2**: 36-43.

Morris, O.J. 1932. Copying: Some Old Theories and Some New Methods. *British Journal of Photography,* Dec. 9, 739-741, 757-759.

Mortimer, F.J., and S.L. Coulthurst. [1909] 1973. *The Oil and Bromoil Processes.* [London: Hazell, Watson & Viney]. Reprinted in Bunnell, Peter. *Nonsilver Printing Processes.* New York: Arno Press.

Moss, G.M. 1895. The Preparation of Salted Silver Paper. *Amateur Photographer,* Aug. 9, 90.

Moss, G.M. 1896. Plain Salted Papers and How to Prepare Them. *Photogram* (London) **3**: 167.

Moulton, H.D. 1877. Dry Versus Wet. *Photographic Mosaics,* 77-82.

Muehler, L.E., and J.I. Crabtree. 1945. A Single-solution Intensifier For Very Weak Negatives. *Photographic Society of America Journal* **11**(2): 81-122.

NFPA. 1974. *Cellulose Nitrate Motion Picture Film.* NFPA no. 40. Boston, M.A.: National Fire Protection Association.

Nadeau, Luis. 1982. *History and Practice of Carbon Processes.* Fredericton, N.B.: Atelier Luis Nadeau.

Nadeau, Luis. 1984. *History and Practice of Platinum Printing.* Fredericton, N.B.: Atelier Luis Nadeau.

Nadeau, Luis. 1985. *Oil and Bromoil.* Fredericton, N.B.: Atelier Luis Nadeau.

National Archives of Canada. 1989. *Headquarters Accommodation Program: Requirements Statement for the National Archives of Canada Headquarters Accommodation.* Ottawa: NA.

Neblette, C. B. 1938. *Photography: Its Principles and Practice.* 3rd ed. New York: D. Van Nostrand.

Newens, Frank R. 1931. *The Technique of Color Photography.* Boston: American Photographic Publishing Co.

Newhall, Beaumont. 1958. Ambrotype, a Short and Unsuccessful Career. *Image* **7**: 171-177.

Newhall, Beaumont. 1961. *The Daguerreotype in America*. 3rd rev. ed. New York: Dover Publications.

Newhall, Beaumont. 1964. *The History of Photography, from 1839 to the Present*. 4th ed. New York: Museum of Modern Art.

Newhall, Beaumont. 1967. *Latent Image: The Discovery of Photography*. New York: Doubleday.

Newman, Alan B. 1979. *A Guide to Platinum/Palladium Printing. An Annotated Bibliography: A Guide to Modern Papers Useful in the Process*. Ashfield, M.A.: n.p.

Newton, H.J. 1875. How to Make Emulsions. *Photographic Times* (New York) 5(56): 186-188.

Nietz, A.H., and K. Huse. 1918. The Sensitometry of Photographic Intensification. *Journal of the Franklin Institute* **185**(1107): 389-408.

Nitze, H. 1932. Paper, Developer and Bleach in Sepia Toning. *British Journal of Photography*, Aug. 486-487.

Norris, D.H. 1983. The Proper Storage and Display of a Photographic Collection. *The Book and Paper Annual of the AIC* 2: 66-81.

Ostroff, Eugene. 1965. Early Fox Talbot Photographs and Restoration by Neutron Irradiation. *Journal of Photographic Science* **13**(5): 213-227.

Ostroff, Eugene. 1978. The Calotype and the Photographer. *Journal of Photographic Science* **26**(2): 83-88.

Ostroff, Eugene. 1978. Rescuing Nitrate Negatives. *Museum News* (Washington, D.C.) **57**(1): 34-42.

Ostroff, Eugene. 1979. Herschel and Talbot: Photographic Research. *Journal of Photographic Science* **27**: 73-80.

Owerbach, D.A. 1983. Colorimetric Determination of Residual Thiosulphate (Hypo) in Processed Paper. *Journal of Applied Photographic Engineering* 9 (2): 66-70.

Padfield, T. 1966. The Control of Relative Humidity and Air Pollution in Show-Cases and Picture Frames. *Studies in Conservation* **11**(1): 8-30.

Padfield, T., et al. 1982. Trouble in Store. In *Science and Technology in the Service of Conservation*, 1982, IIC Preprints, 24-27. London: International Institute for Conservation of Historic and Artistic Works.

Parker, J.T., and L.J. Sugden. 1963. Determining the Resistance of Photographic Emulsions to Damage During Processing. *Photographic Science and Engineering* **7**(1): 41-47.

Parsons, T.F., et al. 1979. To RC or Not to RC. *Journal of Applied Photographic Engineering* 5(2): 110-117.

Pearlstein, E.J., et al. 1982. Effects of Eraser Treatment on Paper. *Journal of the American Institute for Conservation* **22**(1): 1-12.

Perrin, F.H., and J.H. Altman. 1952. Studies in the Resolving Power of Photographic Emulsions vs. the Effect of Reduction and Intensification. *Journal of the Optical Society of America* **42**(7): 462-467.

Perron, Johanne. 1989. The Use of FTIR in the Study of Photographic Materials. In *Topics in Photographic Preservation* 3: 112-122. Washington, D.C.: American Institute for Conservation. Photographic Materials Group.

Peterich, Gerda. 1957. Louis Désiré Blanquart-Evrard: The Gutenberg of Photography. *Image* 6(4): 80-90.

Pittaro, Ernest M., ed. 1977. *Photo-Lab Index: The Cumulative Formulary of Standard Recommended Photographic Procedures*. Dobbs Ferry, N.Y.: Morgan & Morgan.

Pizzighelli, G., and Baron Arthur Hübl. [1866] 1973. *Platinotype*. [London: Harrison and Sons]. Reprinted in Bunnell, Peter. *Nonsilver Printing Processes*. New York: Arno Press.

Pobboravsky, I. 1971. *Study of Iodized Daguerreotype Plates*. Master's thesis, Rochester Institute of Technology.

Pobboravsky, I. 1978. Daguerreotype Preservation: The Problems of Tarnish Removal. *Technology and Conservation*, Summer, 43.

Pope, C.I. 1963. Stability of Residual Thiosulphate in Processed Microfilm. *Journal of Research of the National Bureau of Standards* 67C(1): 15-24.

Pouradier, J., and A.M. Mailliet. 1965. Conservation des documents photographiques sur papier. I: Influence du thiosulfate résiduel et des conditions de stockage [Conservation of Photographic Documents on Paper. I: Influence of Residual Thiosulfate and Storage Conditions]. *Science et Industries Photographiques* 36(2-3): 29-42.

Powers, S. 1978. Why Exhibit? The Risks versus the Benefits. *American Archivist* 41(3): 297-306.

Preservation Publishing Company. 1989. Personal communication from H. Wilhelm. Data to be published by Preservation Publishing Company.

Queval. 1878. A Complete Treatise on the Taupenot Process. *Photographic Times* 8(88): 84-86, 102-105.

Reed, V. 1978. *Emulsion Stripping*. Report. Rochester, N.Y.: Eastman Kodak.

Reed, V. 1981. How to Work Restoration Magic on Wrinkled Negatives. *PhotographiConservation* 3(4): 4-6.

Reed, V. 1987. *Photographic Retouching*. Kodak Publication, no. E-97. Rochester, N.Y.: Eastman Kodak Co.

Reilly, J.M. 1978. The Albumen Print. *Camera*, no. 2, pages unknown.

Reilly, J.M. 1978. The Manufacture and Use of Albumen Paper. *Journal of Photographic Science* 26 (4): 156-161.

Reilly, J.M. 1980. *The Albumen and Salted Paper Book*. Rochester, N.Y.: Light Impressions Corp.

Reilly, J.M. 1982. Albumen Prints: A Summary of New Research About Their Preservation. *Picturescope*, Spring, 36.

Reilly, J.M. 1984. *Evaluation of Storage Enclosure Materials for Photographs Using the ANSI Photographic Activity Test*. Unpublished Final Narrative Report of Accomplishment for National Museum Act Grant #FC-309557.

Reilly, J.M. 1986. *Care and Identification of 19th-Century Photographic Prints*. Kodak Publication, no. G-2S. Rochester, N.Y.: Eastman Kodak Co.

Reilly, J.M., et al. 1982. Image Deterioration in Albumen Photographic Prints. In *Science and Technology in the Service of Conservation, 1982, IIC Preprints*, 61-65. London: International Institute for Conservation of Historic and Artistic Works.

Reilly, J.M., et al. 1988. *Photo Enclosures Research and Specifications*. Paper presented at the National Archives and Records Administration Conference, April 12, 1988, Washington, D.C.

Rexroth, Nancy. 1978. *The Platinotype 1977*. 3rd ed. Missoula, M.T.: Formulary Press.

Richardson, Carlos. 1979. Palladium Printing. *Camera*, no. 2, pages unknown.

Rinhart, F. and M. 1969. *American Miniature Case Art*. New York: Barnes and Co.

Rinhart, F. and M. 1975. A Search for Colour. *New Daguerreian Journal* 3(3): 8-12.

Rinhart, F. and M. 1981. *The American Daguerreotype*. Athens, G.A.: University of Georgia Press.

Ritzenthaler, M.L., et al. 1984. *Archives and Manuscripts: Administration of Photographic Collections*. Chicago: Society of American Archivists.

Rosenblum, Naomi. 1984. *A World History of Photography*. New York: Abbeville Press.

Rothberg, Samuel W. 1976. *Photogravure Handbook*. Chicago: Rye Press.

Rothschild, N. 1973. How to Use the "Classic" Toners. *Popular Photography*, Oct., 106-109, 203, 212.

Royal Photographic Society. 1981. *Sir John Herschel and the Invention of Photography. Royal Photographic Society National Centre of Photography Exhibition at Bath*. London: Eastman Kodak Co.

Rudd, R.G. 1950. Copying the Black-and-White Print. *Photographic Society of America Journal*, section B, June, 30-38.

Rudisill, R. 1971. *Mirror Image: The Influence of the Daguerreotype on American Society*. Albuquerque: University of New Mexico Press.

Runyan, I.V. 1956. The Aging of Photographic Film Products. *Photographic Engineering* 7(2): 111-117.

Russell, H.D., and J.I. Crabtree. 1932. The Reducing Action of Fixing Baths on the Silver Image. *Journal of the Society of Motion Picture Engineers*, Mar., 371-397.

Sack, S.P., and N. Stolow. 1978. A Micro-Climate for a Fayum Painting. *Studies in Conservation* 23(2): 47-56.

Sano, K. 1969. The Alkaline Hydrolysis of Yellow Azomethine Dyes. *Journal of Organic Chemistry* 34 (7): 2076-2080.

Schaaf, Larry. 1977. Sir John Herschel's 1839 Royal Society Paper on Photography. *History of Photography* 3(1): 47-60.

Schaaf, Larry. 1980. Herschel, Talbot and Photography, Spring 1831 and Spring 1839. *History of Photography* **4**(3): 181-204.

Schaaf, Larry. 1982. Anna Atkins' Cyanotypes: An Experiment in Photographic Publishing. *History of Photography* **6**(2): 151-172.

Scharf, A. 1975. *Pioneers of Photography.* New York: Harry Abrams.

Scheinmann, David. 1978. How to Date the Carte de Visite. *Photographic Society of America Journal* **44** (9): 22-23.

Schnauss, Julius. 1889. *Collotype and Photo-Lithography Practically Elaborated.* London: Iliffe & Sons.

Schramm, H.P., and B. Hering. 1982. *Historische Malmaterialien und Möglichkeiten ihrer Identifizierung.* Dresden: Hochschule für Bildende Kunste.

Schwalberg, Bob, Henry Wilhelm and Carol Brower. 1990. Going! Going!! Gone!!! *Popular Photography* **97**(6): 37-49, 60.

Scopick, David. 1979. *The Gum Bichromate Book.* Rochester, N.Y.: Light Impressions Corp.

Scott, B.A. 1982. Radiographic Image Enhancement. *British Journal of Photography* **129**(6367): 860.

Scovill Manufacturing Co. 1871. How to "Work" Paper. *Photographic Times* (New York) **1**(9): 129-132.

Scribner, B.W. 1939. Summary Report of Research at the National Bureau of Standards on the Stability and Preservation of Records on Photographic Film. *Journal of Research of the National Bureau of Standards* (Washington, D.C.), Nov. 16, 1-17.

Sedlaczek, E. 1928, 1929. Selenium Toning Processes [Die Tonung mit Selenverbindungen]. *British Journal of Photography,* Dec. 28, 784-785; Jan. 4, 4-6; Jan. 18, 29-31; and Jan. 25, 44-46.

Severson, D.G. 1987. The Effects of Exhibition on Photographs. *Picturescope* **32**(4): 133-135.

Shaw, Susan. 1983. *Overexposure: Health Hazards in Photography.* Carmel, C.A.: Friends of Photography.

Sheppard, S.E. 1927. Behaviour of Gelatin in the Processing of Motion Picture Film. *Transactions of the Society of Motion Picture Engineers* **11**(32): 707-727.

Sipley, Louis Walton. 1951. *A Half-Century of Colour.* New York: Macmillan.

Smith, M.A. 1981. *Matting and Hinging of Works of Art on Paper.* National Preservation Office Publication. Washington, D.C.: Library of Congress.

Smith, Merrily A., et al. 1984. Pressure-Sensitive Tape and Techniques for Its Removal from Paper. *Journal of the American Institute for Conservation* **23** (2): 101-113.

Smith, T.D. 1953. The Effect of Environment on the Aging of Photographic Film. *Journal of Photographic Science* 1: 138-144.

Snelling, Henry H. [1849] 1970. *The History and Practice of the Art of Photography*. Reprint. Hastings-on-Hudson, N.Y.: Morgan & Morgan.

Snow, V.F., and D.B. Thomas. 1966. The Talbotype Establishment at Reading, 1844-1847. *Photographic Journal* (London), no. 106, 58.

Sobieszek, Robert. 1974. *The Collodion Process and the Ferrotype*. New York: Morgan & Morgan.

Southworth, M.G. 1979. *Color Separation Techniques*. 2nd ed. Lavonia, N.Y.: Graphic Arts Publishing.

Spencer, D.A. 1947. Tone Rendering in the Reproduction of Photographs. *Photographic Journal* (London) **87B**: 94-104.

Spencer, D.A., ed. 1973. *The Focal Dictionary of Photographic Technologies*. London: Focal Press.

Spencer, D.A. 1979. *D.A. Spencer's Colour Photography in Practice*. Rev. ed. by L.A. Mannheim and Viscount Hansworth. London: Focal Press.

Stecher, Paul G., ed. 1968. *The Merck Index: An Encyclopedia of Chemicals and Drugs*. N.J.: Merck & Co.

Stender, W.W., and W. Evans. 1974. The National Personnel Records Centre Fire: A Study in Disaster. *American Archivist* **37**(4): 521-549.

Stieglitz, Alfred. 1893. Points on Developing Cold-Bath Platinotypes. *American Amateur Photographer* **5**: 209.

Still, John S. 1953. Library Fires and Salvage Methods. *American Archivist* **16**(2): 145-153.

Stroebel, L., et al. 1986. *Photographic Materials and Processes*. Boston: Focal Press.

Sturge, John M., ed. 1977. *Neblette's Handbook of Photography and Reprography Materials, Processes and Systems*. 7th ed. New York: Van Nostrand Reinhold.

Sturge, John M., et al., eds. 1989. *Imaging Processes and Materials: Neblette's Eighth Edition*. New York: Van Nostrand Reinhold.

Sutton, Thomas. 1855. *The Calotype Process: A Handbook to Photography on Paper*. London: Joseph Cundall.

Sutton, Thomas. 1856. Yellowness in the Lights of Positives. *Photographic Notes* **1**(6): 63.

Sutton, Thomas. 1860. Artistic Positive Printing. *American Journal of Photography and Allied Arts and Sciences* (New York) **2**(17): 257-262.

Swan, A. 1978. Conservation Treatments for Photographs. *Image* **21**(2): 24-33.

Swan, Alice. 1981. Conservation of Photographic Print Collections. *Library Trends* **30**(2): 29-39.

Swan, A. 1981. Conservation Treatment for Photographs: A Review of Some of the Problems, Literature and Practices. In *The Care and Conservation of Photographic Materials*, 5-9. London: Crafts Council.

Swan, A. 1981. The Preservation of Daguerreotypes. In *American Institute for Conservation of Historic and Artistic Works Preprints of Papers Presented at the Ninth Annual Meeting, Philadelphia, Pennsylvania, 27-31 May 1981*, 164-172. Washington, D.C.: AIC.

Swan, A., et al. 1979. Daguerreotypes: A Study of the Plates and the Process. *Scanning Electron Microscopy* **11**(1): pages unknown.

Swedlund, Charles. 1974. *Photography: A Handbook of Historical Materials and Processes*. New York: Holt, Rinehart and Winston.

Taft, Robert. [1938] 1964. *Photography and the American Scene: A Social History, 1839-1889*. Reprint. New York: Dover Publications.

Talbot, William Henry Fox. 1839. Some Account of the Art of Photogenic Drawing. *London and Edinburgh Philosophical Magazine and Journal of Science* **14**: 196-208.

Talbot, William Henry Fox. [1841] 1842? Calotype. [*Civil Engineering and Architecture Journal*, Aug., pages unknown]. Reprinted in *Journal of the Franklin Institute of the State of Pennsylvania and Mechanics Register*, Feb., 89-93.

Talbot, William Henry Fox. 1864. On photography without the use of silver. *British Journal of Photography* **11**: 495.

Talbot, William Henry Fox. 1959. *Image* **8**(2): entire issue.

Talbot, William Henry Fox. [1844-1846] 1969. *The Pencil of Nature*. [London]. Reprint, with intro. by Beaumont Newhall. New York: Da Capo Press.

Talbot, William Henry Fox. 1976. *Camera* **55**(9): entire issue.

Teasdale, Washington. 1854. Photography Processes. *Journal of the Photographic Society* **1**(13): 161-162.

Tennant, John A. 1899. Platinotype Processes. *The Photo-Miniature*, Oct.

Tennant, John A. 1900. The Carbon Process. *The Photo-Miniature*, no. 17.

Tennant, John A. 1900. Albumen and Plain Paper Printing. *The Photo-Miniature*, Dec., 357-386.

Tennant, John A. 1900. The Blue Print and Its Variations. *The Photo-Miniature*, Jan.

Tennant, John A. 1902. Platinotype Modifications. *The Photo-Miniature*, July.

Tennant, John A. 1910. Oil and Bromoil Printing. *The Photo-Miniature*, Mar.

Tennant, John A. 1922. Bromoil Prints and Transfers. *The Photo-Miniature*, no. 186.

Tennant, John A., and Ward. 1922. Kallitype and Allied Processes: A Collection of Practical Methods for the Preparation of Photographic Printing Paper With the Iron Salts. Kallitype, Revised to Date, Iron-Silver, Uranium, Copper and Platinum Papers: With Formulas and Working Instructions. *The Photo-Miniature* **16**(185): pages unknown.

Thomas, David B. 1964. *The First Negatives: An Account of the Discovery and Early Use of the Negative-Positive Photographic Process*. London: The Science Museum, and Her Majesty's Stationery Office.

Thomson, G. 1964. Relative Humidity: Variation with Temperature in a Case Containing Wood. *Studies in Conservation* **9**(4): 153-168.

Thomson, G. 1977. Stabilization of RH in Exhibition Cases: Hygrometric Half-time. *Studies in Conservation* **22**(2): 85-102.

Thomson, G. 1986. *The Museum Environment*. 2nd ed. London: Butterworths.

Thomson, James. 1904, 1907, 1922. Kallitype. *The Photo-Miniature*, Dec. 1904, Sept. 1907, Jan. 1922.

Time-Life. 1970. *Color*. Life Library of Photography. New York: Time-Life Books.

Time-Life. 1970. *The Print*. Life Library of Photography. New York: Time-Life Books.

Time-Life. 1972. *Frontiers of Photography*. Life Library of Photography. New York: Time-Life Books.

Time-Life. 1982. *Caring for Photographs: Display, Storage, Restoration*. Life Library of Photography. Rev. ed. Alexandria, V.A.: Time-Life Books.

Tissandier, Gaston. [1877] 1878. *A History and Handbook of Photography*. [New York: Scovill]. 2nd rev. ed., by J. Thomson with Appendix by William Henry Fox Talbot. London: Sampson Low, Marston, Searle and Rivington.

Todd, H.N., and R.D. Zakia. 1974. *Practical Sensitometry: The Study of Tone Reproduction*. 2nd ed. Dobbs Ferry, N.Y.: Morgan & Morgan.

Torigoe, M., et al. 1984. Kuroshiro shashin no choki hozonho [A Challenge in Preservation of Black-and-White Photographic Images]. *Scientific Publication of the Fuji Photo Film Co., Ltd.* **39**(29): 31-36.

Towler, John. 1876. Dry Plates. *Photographic Mosaics*, 88-94.

Towler, John. [1864] 1969. *The Silver Sunbeam*. [New York: Joseph Ladd]. Reprint. Hastings-on-Hudson, N.Y.: Morgan & Morgan.

Townsend, F. 1855. On the Quality of Paper Required for Photographic Purposes, More Particularly for the Waxed-Paper Process. *Liverpool Photographic Journal* **2**(15): 37-38.

Tuite, R.J. 1979. Image Stability in Color Photography. *Journal of Applied Photographic Engineering* **5**(4): 200-207.

Vitale, Timothy, and Jane Sugarman. 1989. *Observations on the Drying of Paper and Their Application to Treatment*. Paper presented at the A.I.C. Annual Conference. Cincinnati, O.H. May 31-June 4.

Vittum, R.W., and A. Weissberger. 1954. The Chemistry of Dye-Forming Development. *Journal of Photographic Science* 2: 81-96.

Vogel, Herman. 1973. *The Chemistry of Light and Photography*. Facsimile ed. New York: Arno Press.

Vogt, Diane. 1987. *A Draft Photographic Thesaurus*. Smithsonian Archives Photo Survey Project. Washington, D.C.: Smithsonian Institution Archives.

Volent, Paula. 1989. *Evaluation of Adhesives for Application to Works of Art on Paper by Accelerated Aging*. Paper presented at the A.I.C. Annual Conference. Cincinnati, O.H.: May 31-June 4.

Wächter, Otto. 1982. *Restaurierung und Erhaltung von Büchern, Archivalien und Graphiken*. 3 Aufl. Wien: Bohlau.

Wade, Kent E. 1978. *Alternative Photographic Processes*. Dobbs Ferry, N.Y.: Morgan & Morgan.

Wall, E.J. 1902. The Platinotype Process. *British Journal of Photography* 49: 531, 570, 612, 630.

Wall, E.J. 1927. *Intensification and Reduction: A Critical Résumé of All Known Methods*. Boston: American Photographic Publishing Co.

Wall, E.J. 1929. *Photographic Emulsions: Their Preparation and Coating on Glass, Celluloid and Paper, Experimentally on the Large Scale*. Boston: American Photographic Publishing Co.

Wall, E.J. 1937. *The Dictionary of Photography*. 14th ed. Boston: American Photographic Publishing Co.

Wall, E.J., and F.I. Jordan. 1975. *Photographic Facts and Formulas*. See Carroll, J.S. 1975.

Walworth, Vivian K., and Stanley H. Mervis. 1989. Instant Photography and Related Reprographic Process. In *Imaging Processes and Materials: Neblette's Eighth Edition*, ed. by J.M. Sturge, et al. 181-225. New York: Van Nostrand Reinhold.

Ward, J.P. 1977. The Fox Talbot Collection at the Science Museum. *History of Photography* 2(4): 275-287.

Ware, M.J. 1986. An Investigation of Platinum and Palladium Printing. *Journal of Photographic Science* 34(5-6): 13-25.

Warren, W.J. 1899. *A Handbook of the Platinotype Process of Photographic Printing*. London: Iliffe Sons and Sturmey Ltd.

Waugh, F.A. 1901. Gum-Bichromate Printing. *The Photo-Miniature*, Jan.

Weinstein, Robert, and Booth, Larry. 1977. *Collection, Use, and Care of Historical Photographs*. Nashville, T.N.: American Association for State and Local History.

Welling, William. 1976. *Collectors' Guide to Ninetheenth-century Photographs*. New York: Collier.

Weyde, Edith. 1955. Das Copyrapid-Verfahren der Agfa [The Agfa Copyrapid Process]. *Mitteilungen aus den Forschungs-laboratorien der Agfa* 1: 262-266.

Weyde, E. 1962. Grösse und Form des entwickelten Silberkornes und seine Beziehungen zu bildwichtigen Eigenschaften [Size and Shape of the

Developed Silver Grain and its Relationship to Image Properties]. *Photographische Korrespondenz* **98** (1): 7-12.

Weyde, E. 1972. A Simple Test to Identify Gases Which Destroy Silver Images. *Photographic Science and Engineering* **16**(4): 283-286.

Whalley, Geoffrey E. 1961. *Bromoil and Transfer.* London: Fountain Press.

Wheeler, Capt. Owen. 1930. *Photographic Printing Processes.* London: Chapman & Hall, Ltd.

White, Minor, et al. 1969. *French Primitive Photography.* Philadelphia, P.A.: Aperture.

WHIMS. 1988. *WHIMS Core Material: A resource Manual for the Application and Implementation of WHIMS.* Richmond, B.C.: Workers' Compensation Board of British Columbia.

Widmayer, W. 1961. Cold Storage Protects Colour Negatives. *American Cinematographer* **42**: 170-172, 174.

Wiederhold, P.R. 1975. Humidity Measurements. *Instrumentation Technology,* Oct. Reprint. Watertown, M.A.: General Eastern Instruments Corp.

Wilhelm, H. 1977. *Washing Prints and Films.* Unpublished manuscript.

Wilhelm, H. 1978. Storing Colour Materials: Frost Free Refrigerators Offer a Low-Cost Solution. *Industrial Photography* **27**(10): 32.

Wilhelm, H. 1981. Monitoring the Fading and Staining of Colour Prints. *Journal of the AIC* **21**: 49-64.

Wilkinson, W.T. 1894. *Photo-Engraving, Photo-Litho, Collotype, and Photogravure.* London.

Williams, R.S. 1985. Problems with Commercial Storage and Filing Enclosures for Processed Photographic Materials: Chemical Analysis and Recommendations for Suitable Procedures and Materials for Museum and Archival Storage Purposes. In *Printing of Transcript Summaries: Society of Photographic Scientists and Engineers, Second International Symposium, The Stability and Preservation of Photographic Images, August 25-28, 1985, Ottawa,* 16-30. Ottawa: SPSE.

Williams, T.I. 1978. *Pigment Printing Processes.* London: Royal Photographic Society.

Wilson, Edward L. [1868] 1978. *The American Carbon Manual.* Reprint. New York: Arno Press.

Wilson, T. 1935. *The Practice of Collotype.* Boston: American Photographic Publishing Co.

Wilson, William K., and Carl J. Wessel. 1984. *Guidelines for Environmental Conditions in Archives and Libraries.* National Archives and Records Service Technical Report. Washington, D.C.: National Institute for Conservation.

Witkin, Lee D., and Barbara London. 1979. *The Photograph Collector's Guide.* Boston: New York Graphic Society.

Wolf, Linda. 1977. How to Make Calotypes: Rediscovering an Almost Lost Art. *Petersen's PhotoGraphic Magazine*, May, 96-103.

Wolin, Jeffrey A. 1979. P.O.P. (Kodak Studio Proof). *Camera* 58(2): 30-31.

Wood, Rupert Derek. 1975. *The Calotype Patent Lawsuit of Talbot vs. Laroche, 1854*. Bromley: The author.

Woodbury, Walter E. 1896. *The Encyclopaedic Dictionary of Photography*. New York: Scovill & Adams.

Woodlief, Thomas Jr., ed. 1973. *SPSE Handbook of Photographic Science and Engineering*. New York: John Wiley & Sons.

Wyard, John. 1880. The Production of Photographic Images on Plates of Glass or Porcelain, by the Action of Light, Enabling Them to be Permanently Fixed by Being Burnt In With Ceramic Colours. *American Journal of Photography and the Allied Arts and Sciences* (New York) 2(23): 361-367.

Zinkham, Helena, and Elizabeth Betz Parker. 1986. *Genre/Form and Physical Characteristics Terms: A Thesaurus for Prints, Photographs, Drawings, Ephemera, and Other Graphic Materials*. Washington, D.C.: Library of Congress.

Zucker, H. 1972. Old-time Processes: How to Identify and Date Them. *Popular Photography*, Dec., 99-101, 170-216.

Index

Fundamentals of Photograph Conservation:

A Study Guide

Along with the recognition of photography as a fine art has come a new appreciation of the history of photography and the need to preserve photographs scientifically as historical artifacts. The museum curator and the archival conservator thus become mutually interdependent, with conservation recognized as a legitimate specialization, and photographs appreciated for their physical as well as their other properties.

In this important volume, the National Archives of Canada shares ongoing scientific staff experiments exploring many areas of photograph conservation and raises standards yet higher in this emerging specialty.

Yousuf Karsh

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