PHOTOGRAPHIC MATERIALS CONSERVATION CATALOG

The American Institute for Conservation of Historic and Artistic Works

Photographic Materials Group

FIRST EDITION
November 1994

INPAINTING OUTLINE

The **Photographic Materials Conservation Catalog** is a publication of the Photographic Materials Group of the American Institute for Conservation of Historic and Artistic Works.

Copies of outline chapters of the **Photographic Materials Conservation Catalog** may be purchased from the American Institute for Conservation of Historic and Artistic Works, 1717 K Street, NW., Suite 301, Washington, DC 20006 for $15.00 each edition (members, $17.50 non-members), plus postage.

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STATEMENT OF PURPOSE

The purpose of the **Photographic Materials Conservation Catalog** is to compile a catalog of conservation treatment procedures and information pertinent to the preservation and exhibition of photographic materials. Although the catalog will inventory techniques used by photographic conservators through the process of compiling outlines, the catalog is not intended to establish definitive procedures nor to provide step-by-step recipes for the untrained. Inclusion of information in the catalog does not constitute an endorsement or approval of the procedure described. The catalog is written by conservators for conservators, as an aid to decision making. Individual conservators are solely responsible for determining the safety, adequacy, and appropriateness of a treatment for a given project and must understand the possible effects of the treatment on the photographic material treated.

The ongoing process of creating and maintaining a photographic materials conservation catalog benefits the work of photographic conservators in several ways, not the least of which is the possibility of understanding colleagues' work more clearly and sharing knowledge to advance the expertise of the field as a whole. The process of compiling a catalog provides a forum for information exchange among practicing photograph conservators. At this time, when professional photograph conservation is still a young field, when there is a shortage of published information on actual conservation treatments, and when the behaviour and degradation processes of photographic materials are still imperfectly understood, the need for this kind of information exchange is acutely necessary.

At the 1989 Kansas City Winter Meeting, the Photographic Materials Group nominated a catalog organizing committee to survey the membership about initiating a photographic materials conservation catalog similar in concept to the **Paper Conservation Catalog** (PCC). Committee members, Nora Kennedy, Sarah Wagner, and John McElhone, surveyed the membership to determine if 1) a catalog was desired, 2) if so, were the proposed topics and PCC format acceptable, and 3) would there be volunteers to compile and contribute to outlines. Survey results were presented at the AIC/PMG Meeting in Richmond, 1990. The membership endorsed the idea of starting a conservation catalog, with the understanding that a rigid production schedule could not be initiated due to the limited size of the membership and volunteer nature of the project. The first three topics for which there were interested compilers included *Inpainting* (Debbie Hess Norris, compiler), *Exhibits* (Doug Severson and Stephanie Watkins, compilers), and *Cased Objects* (John McElhone, compiler).

INPAINTING OF PHOTOGRAPHIC PRINTS

4.0

This outline addresses the inpainting of damaged *original* photographic surfaces and is designed to provide a list of materials and techniques used by photographic conservators. This outline does not address compensation methods and techniques for losses in a primary support or retouching techniques used in the production of copy photographs (non-originals).

4.1 Purpose:

To restore visual unity to a damaged photographic image.

4.2 Factors to consider

4.2.1 Nature and type of photograph and its intended use in relation to exhibition and storage, as well as its relationship to the collection and/or institution in which it is housed.

4.2.2 Conservator's treatment must be governed by informed respect for the aesthetic, conceptual, historic, and physical integrity of the photograph. This respect is based on thorough understanding of the object that comes from careful examination, curatorial consultation, and historical research. Inpainting must be consistent with the photographer's original intent. It may be necessary to consult with a living photographer prior to compensation.

4.2.3 Type of photographic process and its associated component structure, character, and condition in terms of tonality, opacity, surface character or reflectance, solubility parameters, and solvent sensitivity.

4.2.4 Stability, reactivity, solubility, workability, and reversibility of selected media. Preference may be influenced by conservator's experience with specific inpainting media. Likewise, the effects of subsequent conservation treatment procedures on inpainting must be considered. It is imperative that the potential reactivity between all considered or proposed inpainting media (including isolating layers and coatings) and the photograph requiring treatment be very carefully assessed.

4.2.5 Techniques and materials should not, to the best of current knowledge, impede future treatment or scientific investigation or react with components of the photograph to cause deterioration such as staining, fading, or discoloration. Photographic activity testing may be required to evaluate the possible effects of various inpainting materials on photographs. Light and dark stability testing is required to assess fading characteristics of inpainting media.

4.2.6 Size, nature (visual impact), and location of damage.

4.2.7 Accurate and thorough documentation prior to inpainting. Inpainting should be detectable by common methods of examination, including microscopic, ultraviolet light, raking and/or specular light.

4.3 Isolating Layer

4.3.1 General

A. An isolating layer helps to protect the underlying photograph from inpainting materials applied to the surface and allows greater ease in reversing inpainting.

B. Materials used as an isolating layer will be extremely difficult to remove entirely.

C. An isolating layer also acts as a sizing agent on exposed or abraded paper fibers.

D. Consideration must be given to the solubility parameters of the photographic binder, the isolating material, and the intended inpainting media. Ideally, the photograph's binder should not be affected by the application or removal of these additional materials.

4.3.2 Gelatin

A. Gelatin is the most traditional isolating layer used, because of its compatibility with proteinous binders.

B. Its tendency to swell but not dissolve in cold water can allow removal of water-soluble inpainting materials without loss of the isolating layer itself.

C. It can be difficult to apply more than one layer of water-based media over gelatin, as it can "pick up" or become lumpy.

D. It may be difficult to safely remove a gelatin isolating layer from a gelatin binder because the two will, by definition, have the same or very similar solubility parameters.

4.3.3 Cellulose Ethers

A. Cellulose ethers are generally water-soluble materials with relatively long shelf lives. For more in-depth discussion of these materials, please refer to the Paper Conservation Catalogue section that describes cellulose ethers (46.3.1.C.1-7).

B. These materials are very easily reversed in water, yet resistant to most other solvents.

C. It can be difficult to apply more than one layer of water-based media over methyl cellulose, as it is water-soluble and tends to "pick up."

D. It is possible that sodium carboxymethyl cellulose may form insoluble complexes in the presence of metal ions.

4.3.4 Acrylic Emulsions

A. An acrylic emulsion is defined in ASTM D4302 as a stable aqueous dispersion of polymers or copolymers of acrylic acid, methacrylic acid, or acrylonitrile--also called latex, acrylic latex, or polymer emulsion paint. Manufacturers add unspecified amounts of other ingredients as thickeners, wetting agents, fungicides, and so on.

B. Acrylic emulsion coatings should remain readily soluble in toluene, acetone, petroleum benzine, or alcohol.

C. Once dry, acrylic emulsions become insoluble in water. If an acrylic emulsion is used on a photograph with a water-soluble binder, it is thus possible to remove the isolating layer and the inpainting on top of the layer with an organic solvent that will not disturb the binder. It may be inappropriate to use acrylics with solvent-sensitive binders such as collodion or on coated/waxed photographs.

D. Because of the hydrophobic nature of acrylics, it can be difficult to paint on top of the layer with more than a single coat of water-based media.

E. Acrylic emulsions have a tendency to shrink when they dry owing to the evaporation of the water in the system. It may be difficult to get a smooth and even coating.

4.3.5 **Acrylic Resins**

A. Acrylic resins such as Acryloid B-67 or B-72 can be dissolved in organic solvents selected by the conservator using them.

B. They can be applied in very thin coats and tend to dry fairly quickly.

C. If an acrylic resin is used on a photograph with a water-soluble binder, it is possible to remove the isolating layer and the media on top of the layer with an organic solvent that will not disburb the binder.

D. Because of the hydrophobic nature of acrylics, it can be difficult to paint on top of the layer with water-based media.

E. If used on photographs with very thin binder layers or no binder at all, acrylic resins can quickly penetrate the paper surface and darken the paper.

4.4 Inpainting Media

4.4.1 Transparent and Opaque Watercolors

A. Inherent Characteristics, Standards, and References

1. Pigment dispersion in water-soluble gum/resin may include plasticizer, glycerine, wetting agent, and preservative. Opaque watercolors (gouache) contain similar ingredients, with the addition of chalk (calcium carbonate).

2. ASTM D5067 Standard Specification For Artists' Watercolor Paints. This standard establishes requirements of composition, physical properties, performance, and labeling of artists' watercolor paints. Requirements are included for accurate pigment identification, lightfastness, and consistency.

3. The Wilcox Guide to the Best Watercolor Paints

This guide provides a series of paint assessments for tube watercolors in a wide range of colorants and by numerous manufacturers. In combination with ASTM D5067, it allows the conservator to evaluate lightfastness and pigment formulations of current working palette; to identify the appropriate or "best" manufacturer when a specific colorant (such as a magenta or cobalt blue) is required; to establish "equivalency" between artist-quality and second-range paints when possible (many of the earth colors, for example, may be of similar quality yet differ substantially in unit price); and to evaluate workability of a particular watercolor paint (many of the synthetically formed iron oxides are significantly less grainy than their natural counterparts). **It should be noted that much of the specific pigment content information contained within this useful guide is likely to be outdated.**

4. Many manufacturers will provide references on lightfastness and other characteristics upon request.

B. Brands and Specific Qualities

1. Photographic retouching materials (See 4.4.8)

2. Winsor & Newton pan watercolors appear to be more transparent than tube watercolors. (Tube watercolors often contain a higher percentage of pigment; however, these pigments should be identical in composition.) The representative at Daniel Smith, Inc., stated that the Winsor & Newton Cotman series colors contain less pigment and more synthetics than Winsor & Newton Artist series colors. Therefore, he felt that the Cotman series colors tended not to be as light stable as the Artist series colors. In consulting The Wilcox Guide to the Best Watercolor Paints, one may find that this statement is not necessarily true. For many colors, the Cotman series rated as good and occasionally better than the Artist series colors (ivory, black, and burnt umber to name a few) (Derby).

C. Lightfastness and Stability Characteristics

1. Watercolors are at great risk to damage (fade or color shift) from light exposure because pigments are not well protected by binder (as in oil or acrylic paints). Small quantities of pigment utilized in inpainting may further contribute to their reactivity. Specific and useful information on lightfastness is available.

2. In ASTM D5067, pigments meeting lightfastness requirements (ASTM4303) are provided and identified by common name, color index, name and number, and lightfastness category. Note specifically the inclusion in this list of a wide range of red, orange, and purple pigments - tonalities often essential to the "successful" inpainting of printed-out photographic print materials.

3. Upon exposure to light, mixtures of colors may fade at a faster rate (compared with non-mixtures) or may develop color shift.

4. Potential reactivity between specific pigments and a photograph's final image material must be evaluated. Some pigments may require additional photographic activity testing (Dobruskin and Hendriks).

D. General Observations, Techniques, and Special Applications

1. Watercolors are easily applied to and compatible with traditional isolating layers of methyl cellulose or gelatin. An isolating layer is essential. (For example, if paper fibers from the photograph's primary support are exposed, pigment may bind to the fibers and become difficult to remove safely.)

2. A wide range of colorants are available. Colorants can be manipulated and layered to create a translucent effect that is often "photographic" in nature. Conservators should note that some pigments are inherently more transparent than others. Careful pigment selection is extremely important. (Burnt sienna is a transparent pigment, whereas burnt umber is semi-opaque. Likewise, quinacridon scarlet is a transparent pigment, whereas cadmium red is considerably more opaque.)

3. Methyl cellulose may be added to increase "bulk" and reduce wicking of the colorant. Watercolors can be applied using a dry brush technique with small brushes designed for retouching work. When necessary, transparent washes or glazes of color may also be achieved.

4. Watercolors can be further modified (to increase viscosity and/or gloss) by the addition of diluted gelatin, methyl cellulose, or gum arabic solutions. (The tendency of gum arabic to yellow and crack with age must be considered.)

5. Watercolor combined with gelatin may be diluted and applied in thin washes, layer by layer, to achieve desired translucency (Turchan).

6. Watercolor is more readily reversible in water when applied over an isolating layer. Complete reversibility is not always possible. Reversibility in water may be

problematic in those cases in which a photograph's binder layer is severely reactive to moisture. Application of moisture may cause the outer edges of a loss to swell, resulting in planar distortion, a modification of surface gloss, and/or fragmentary loss of binder. Application of moisture to a silver mirrored area may cause localized (irreversible) modification of the fragile surface.

7. Repeated layering of transparent watercolors to achieve high density may be difficult. Opacity is more easily achieved with opaque watercolors. Glossy collodion chloride and silver gelatin printing-out papers may require opacity in inpainting.

8. Insufficient gloss can be a problem. It is difficult to achieve a "high gloss" with watercolors. Additional coatings may be required to achieve gloss (see 4.5).

9. It may be difficult to "wet" onto glossy surfaces. In some cases, it may be difficult to get watercolor paints to flow and adhere evenly onto a smooth surface. (This is often true in inpainting of glossy collodion chloride photographs.) The addition of a small amount of wetting agent to the watercolor may improve its flow characteristics. Likewise, ethanol may be added to improve penetration (Lee).

10. Continuity of a large, smooth surface may be difficult to replicate with brush-applied media. The use of water may roughen the surface of some losses.

4.4.2 Dry Pigments and Pastels

A. Inherent Qualities and Characteristics

1. Pastels consist primarily of pulverized pigments combined with a base or filler, primarily white chalk and mixed into a paste. After the addition of a glutinous binder such as gum tragacanth (traditional), the material is rolled into cylinders and left to dry. Fillers could include chalk, clay kaolin, plaster of paris, titanium and zinc whites aluminum, silica, etc. Other traditional binders include gum arabic, sugar, milk, beer, fish glue, etc. (Watrous, 1957). Modern binders include methyl cellulose and other cellulose derivatives.

2. Pigments can be divided into two main groups, organic and inorganic. Organic pigments are of vegetable, animal or synthetic origins, whereas inorganics are mineral, native earth or synthetic in origin. In 1856,

aniline dyestuffs were introduced providing brilliant and much expanded pallets.

3. Pigments are particulate materials which do not dissolve, but remain dispersed or suspended when mixed with a liquid. They are intended primarily to be held on the surface to which they have been applied by the inclusion of a binder, otherwise they have little affinity for the surface and are easily removed.

4. Pigment particle size is dependant on the degree to which they have been ground. Very finely- ground pigments are generally more appropriate to use as a retouch medium for photographs as they more closely match the size of the silver grains.

B. ***Brands and Specific Qualities***

1. Schmincke pastels are manufactured in Germany and are generally considered to be high quality with regards to pigment filler ratio. They are available primarily in soft grade.

2. Sennelier pastels are handmade in France and are also considered high quality using only pigments chosen for their lightfastness and brilliance in natural binders. They are primarily available in soft grade.

3. Rowney pastels are apparently made with a variety of fine European chalks by the extrusion method as opposed to being pressed or molded making them smoother.

4. Rembrandt pastels are manufactured in Holland by Talens.

5. Grumbacher pastels

6. Winsor & Newton Artists' Dry Ground Pigments

7. Kremer Pigments

8. Daniel Smith Dry Pigments

9. Conservation Materials, Ltd. Dry Colors

C. ***Lightfastness and Stability Characteristics***

Synthetic, aniline dye-based pigments are notoriously susceptible to light damage as are organic lake pigments (Maheux, 1988). The most light-stable pigments tend to be inorganic ones, primarily white, yellow, green, and brown. The least stable tend to be organic pigments in the violet, blue and red range.

D. *General Observations, Techniques and Special Applications*

1. Pastels and dry pigments are most appropriate for use in the retouching of crayon enlargements/solar prints which have been handcolored with pastels, chalks, charcoal, etc. They can also be used for coloring inserts for particularly large areas requiring even toning, prior to being attached.

2. Pigments and pastels are difficult to control as retouch media. The ability to adhere to paper is not consistent and is dependant on how they are applied and what has been done to the paper prior to retouching. For example, a burnished area of an insert will hold the pigment differently than a nonburnished area.

3. Pigments and pastels are difficult to control on small areas and could become permanently imbedded in the cracks of an albumen emulsion as well as other emulsion types that are damaged. For this reason, they are not recommended for use with these materials.

4. Pastels can be shaved from the stick and the pigment applied to the paper with a fine, dry brush or with a tightly wound cotton swab. Some conservators may prefer the use of stomps or tortillions for spreading and smoothing the pigments and pastels.

5. Pastels and dry pigments are friable. Pigment particles can easily be detached from their support.

6. Pastel or dry pigment particles that are considered too large or coarse can be more finely ground in a mortar and pestel.

4.4.3 Graphite Pencils

A. Graphite pencils are used by some photographic conservators to retouch fine detail and small losses in black-and-white prints. The degree of hardness and associated gloss must be carefully controlled and selected. These materials may smudge following application, which can be problematic.

4.4.4 Colored Pencils

A. *Inherent Qualities and Characteristics*

1. In colored pencils, pigments are mixed with clay binders. Modern colored pencils are composed of pigments, fillers, cellulose gum, and wax. Proportions of these components vary significantly.

B. *Brands and Specific Qualities*

1. Carb-Othello Schwan Stabilo colored pencils (commonly referred to as colored chalks) are composed of:
   - 2.5% water-soluble cellulosic binder (added for durability)
   - 70% mineral compounds (responsible for chalk character of these pencils)
   - 10%-30% organic and inorganic pigments
   - 2% metallic soaps
   - 1% preservative

   (Correspondence with manufacturer, April 1992.) These pencils are chalky and friable. As a result, they may spread across the surface of a photograph if retouched areas have not been coated or "fixed." These pencils are soluble in both water and organic solvents.

2. Rexel Cumberland Derwent Studio pencils are composed of a natural clay filler, hydroxypropylcellulose binder, and inorganic pigments (e.g., iron oxides) and organic pigments (lakes). The hardness of these pencils is controlled by the addition (about 15%) of wax. **(Correspondence with Rexel Cumberland Derwent, April 1992.)** These pencils are not friable and will yield a slightly glossy surface. These pencils are generally insoluble in water (component parts may be readily water-soluble) and are slightly soluble in some organic solvents. Individual pencils must be carefully tested for solvent sensitivity and solubility.

   Derwent will provide the consumer with a lightfastness chart that includes a rating system based on the British Standard Blue Wool Scale (BS 1006) Method of measuring colorfastness to light.

   Rexel Cumberland Derwent watercolor pencils are made with water soluble dyes.

3. Berol Prismacolor pencils are composed of a methyl cellulose binder, kaoline and bentonite (for additional strength) clays, and 20%-30% wax and are heavily pigmented with both inorganic and organic pigments. (The high percentage of pigment results in immediate coverage during use.) These pencils are slightly soluble in both water and organic solvents. **(Correspondence with manufacturer, May 1992.)**

C. *Lightfastness and Stability Characteristics*

1. Lightfastness should be of greatest concern with the use of colored pencils. (There are currently no ASTM standards for the labeling of these materials, although it is possible that a standard may be developed and adopted in the near future.) In general, the earth colors (including grays) exhibit excellent to very good lightfastness. Blues, greens, and often yellows, however, are very inconsistent, with stability varying significantly from one manufacturer to another. Finally, the violets, reds, oranges, and pale tints are often problematic and most susceptible to significant fading upon exposure to light. Purple magenta and dark violet are examples of lake pigments. The sheer brightness of these colors can be achieved by no other technique. The lightfastness of these lake pigments is poor.

   It must be noted that colored pencil manufacturers are interested primarily in matching a particular hue, and therefore, if necessary, they will readily alter the specific colorants or pigments utilized. **For this reason, it becomes imperative that conservators perform individual lightfastness testing on the specific pencils (especially non-earth colors) that they wish to use.** In doing so, the method of application may also have to be considered. A variety of application densities may yield different light stability characteristics.

2. See "The Disappearing Fuchas: in Pen, Pencil & Paint (Fall 1993) for a discussion on lightfastness testing conducted on a wide variety of colored pencils using the ISO Blue Wool Reference and ASTM D5383. The main conclusions from this testing were:
   - almost half of the pencils in any line fade significantly
   - some brands are not suitable for fine arts
   - no one brand is clearly superior to all others.

3. A draft document entitled on <u>Standard Practice for the Visual Evaluation of the Lightfastness of Art Materials by the User</u> (ASTM DO 1.57.10) may be adopted in the near future. This standard describes methods for exposing artists' materials to the sunlight and procedures for subjectively interpreting lightfastness by direct comparison with The British Standard Blue Wool Scale. If adopted, this standard could be used easily by the practicing conservator to evaluate specific (and suspect) inpainting materials.

4. Many colored pencil manufacturers have performed lightfastness testing on their products. This information is often available only as a "comparative" rating (one pencil may be ranked excellent when compared with another from the same manufacturer identified as "average") and within specific product lines.

5. Photographic activity testing (PAT) of specific colorants may be required. Preliminary testing performed by the Image Permanence Institute on various gray pencils (from the manufacturers discussed in 4.4.2B) previously yielded excellent results.

6. Because of the high wax content of some colored pencils, there is the slight possibility that upon exposure to high relative humidity conditions, "bloom" formation may occur. This should be of greater concern to the practicing artist when large quantities of these materials are used. Exposure to high relative humidity levels may cause some colored pencils to bleed slightly.

D. ***General Observations, Techniques, and Special Applications***

1. One great advantage to colored pencils is their "containability," i.e., they do not soak into the binder layer or paper fibers of a photographic print. For this reason, they may be considered ideal for the inpainting of small scratches, particularly in situations in which the photograph's binder layer is highly solvent or water-reactive.

2. Isolating layers (methyl cellulose or gelatin have been used) are required to ensure improved reversibility of colored pencils. Selection of the isolating layer should be influenced by the solubility parameters and reactivity of the photograph's binder layer.

3. High density or opacity may be difficult to achieve with colored pencils only. (Derwent Studio pencils tend to be less opaque compared with Berol Prismacolor pencils.)

4. Although a limited palette is available, most of these pencils are very "blendable," allowing for adequate color variation.

5. If used incorrectly, some harder pencils may incise a photograph's glossy or matte surface. Derwent Studio pencils, for example, may be inappropriate if the photograph's paper support is soft or impressionable. For this reason, they are often unsuitable for the inpainting of matte-surfaced photographs but may be considered "ideal" for albumen photographs.

6. Colored pencils may be easily modified with other media. Photographic conservators frequently layer watercolor and colored pencils to create the desired tonality, reflectivity, and opacity. Acrylic emulsion paints may also be used in this manner.

7. Derwent Watercolor Pencils may be applied dry and then blended locally with a wet brush or dipped into water and applied damp in a spot-wise manner. Reversibility of these materials decreases when they are used as a wash (Schenck).

8. For greater control of hue and application, loose media can be shaved or sanded from Carb-Othello pencils and then, much like dry pigments, can be combined with water, methyl cellulose, or an acrylic dispersion binder and applied with a brush. Dry pigments may also be used in this way, allowing for greater control over pigment content and lightfastness characteristics (Harnly).

9. Colored pencils (applied directly or with stumps) are particularly suitable for the inpainting of small damages in matte-surfaced photographs such as salted paper and/or platinum prints.

10. Colored pencils may be sharpened to a fine point and dipped directly in water or an organic solvent, yielding a more matte and dense effect (Schenck).

11. Areas inpainted with colored pencils can be burnished with a bone folder or Teflon burnisher to improve gloss (Reinhold).

12. It may be difficult to inpaint with pencils at the very edge of a loss. In these cases, a fine brush seems best and less damaging (Reinhold).

13. The slight gloss and good range of brown tones of Derwent pencils make them highly suitable for inpainting tiny losses on albumen photographs (Derby).

4.4.5 Acrylic Emulsion Paints

A. *Inherent Qualities and Characteristics*

1. Acrylic emulsion paints are defined in ASTM D4302 as paints containing a stable aqueous dispersion of polymers or copolymers of acrylic acid, methacrylic acid, or acrylonitrile, sometimes termed latex, acrylic latex, or polymer emulsion paint.

2. Acrylic emulsion paints are typically used by photographic conservators for toning inserts but rarely as an inpainting medium applied directly to a photograph's damaged surface.

3. Acrylic emulsion paints should remain readily soluble in toluene, acetone, xylene, petroleum, benzine, or alcohol. (Solubility appears to be a function of how paints were diluted during use.)

4. These paints may not be appropriate to use with surfaces (e.g., wax may dissolve in benzine and varnish or lacquer in acetone due to similar solubility parameters). Likewise, acrylic emulsion paints must not be used for the inpainting of contemporary color photographs, as these materials may be adversely affected by organic solvents.

5. Barrier layers may be used to ensure reversibility.

B. *Brands and Specific Qualities*

1. Liquitex and Golden Artist Colors, Inc., brands of acrylic emulsion paints are typically used by photographic conservators. Both brands are formulated with an acrylic dispersion binder (Rhoplex) modified with additives such as anti-foaming agents, thickeners, fungicides, wetting agents, etc. The difference between these brands of paint appears to be how the paint is "loaded," or the binder/pigment ratio. Owing to ASTM standard D4302, many acrylic emulsion paints are labeled to include pigment

identification, common name, color index name, and lightfastness rating, making careful selection of appropriate pigments possible.

C. *Lightfastness and Stability Characteristics*

1. Yellowing of an acrylic emulsion binder may occur, although this yellowing is often not a function of binder degradation. Yellowing appears to be primarily caused by diffusion or migration of discoloration products from the support and/or exposure to airborne particulates and pollutants. (James Hamm at Buffalo State College has performed extensive tests to evaluate yellowing of the acrylic emulsion binder.)

D. *General Observations, Techniques, and Special Applications*

1. Acrylic emulsion paints change color dramatically as they dry due to the gradual increasing transparency of their milky white binder. This tendency to darken upon drying makes them more difficult to master.

2. Acrylic emulsion paints are opaque and are used by some photographic conservators to replicate the lost baryta layer. Watercolors can be successfully placed on top to create a translucent photographic effect; however, even application may be problematic.

3. With acrylic emulsion paints, it is difficult to modify tone by use of multiple layers.

4. The surface character or final reflectivity of these paints can be modified by additions of gloss or matte media. Photographic activity and further stability testing of these materials is required. (See McCabe and Schenck for discussion of PAT testing of acrylic emulsions and adhesives.)

4.4.6 Acrylic Resin Paints

A. *Inherent Qualities and Characteristics, Standards, and References*

1. These paints are typically used by paintings and decorative objects conservators. In all cases, they consist of pigments bound in an acrylic resin(s).

B. *Brands and Specific Qualities*

1. LeFranc and Bougeois Restoration Colors (recently

renamed Charbonell Restoration Colors) may be preferred. These pigments, which have been preselected for lightfastness, are bound in a resin mixture consisting of isobutyl methacrylate and cyclohexanone. By combining two different resins, working properties may be manipulated and improved, resulting in a final resin with greater flexibility, increased gloss, and less yellowing. These paints remain soluble in benzine. They generally exhibit good saturation, and translucent effects are possible with increased dilution.

2. Bocour manufactured a line of pigments called Magna until recently, when the company went out of business. Magna paints are soluble in xylene and toulene.

C. Lightfastness and Stability Characteristics

D. General Observations, Techniques, and Special Applications

1. Acrylic resin paints may be most suitable for the retouching of water-sensitive binder layers where opacity is required. For example, these paints may be used very successfully for the retouching of glossy silver gelatin printing-out photographs. Use of these paints is also appropriate if reversibility of water-soluble inpainting medium is problematic due to the sensitivity of the particular photographic media.

2. To ensure reversibility (or additional protection to the edges of the damaged binder layer), an isolating layer may be used. This could be accomplished with Acryloid B-72. **Caution:** The use of acrylic resins may be problematic with collodion binder layers, contemporary color materials, and waxed/varnished photographic prints as their solubility characteristics may be similar.

3. Reflectivity or surface character of acrylic resin paints may be modified by the addition of an acrylic varnish or by glazing. With such modification, saturation of colors can be improved.

4. If used directly, acrylic resin paints will typically yield a dry, matte surface. These paints are characteristically leanly bound.

4.4.7 Dye-Based Photographic Retouching Material

A. Inherent Qualities and Characteristics, Standards, and References

B. Brands and Specific Qualities

1. SpoTone (Retouch Methods Co., Inc.) is composed of water-soluble dyes mixed with distilled water (information from manufacturer). The dyes will penetrate or imbibe into a gelatin emulsion. Surfactants may be added to SpoTone to improve "wetability."

2. Ilford Cibachrome Transparent Retouching Dyes are the same as those used in silver-dye bleach prints, according to the manufacturer. They therefore offer the advantage of having the same lightfastness and spectral response as the incorporated azo dyes. According to the manufacturer, these dyes may be removed by immersing the print in a water bath for 30 minutes until the dye lifts out. See Technical Information, <u>Retouching Cibachrome Materials</u>, Ilford Photo Corporation, Copyright 1988, for additional details

3. Kodak Retouching Colors are water-soluble organic dyes related chemically to dyes used to make dye transfer prints.

C. Lightfastness and Stability Characteristics

1. SpoTone dyes are not readily reversible. Some success may be achieved by immersing the retouched photograph face down in a water bath or by local application of ammonia water. Neither technique is generally recommended for historic or deteriorated photographs, as possible consequences could be catastrophic.

2. Although the most lightfast dyes possible are utilized (according to manufacturer), these dyes will shift in color or tonality upon aging (especially with light exposure), often shifting to a warmer, orangish tonality.

3. Kodak Retouching Colors, according to Kodak, have dark stability and light stability characteristics comparable to those of dyes in Ektacolor papers.

4. Retouching dyes are designed to be absorbed into the emulsion layers of prints. Reversibility may be difficult.

5. Cibachrome transparent retouching dyes should have superior dark stability characteristics (when compared with those of dyes utilized in most chromogenic color prints).

6. Stability characteristics of the retouching medium should match those of the photograph requiring inpainting to ensure that these materials fade at a similar rate.

D. General Observations, Techniques, and Special Applications

1. Dye-based materials may be preferred by photographers because "retouched" areas are not readily visible when the photograph is examined in raking light. Their use is very limited for conservators.

4.4.8 Pigment-Based Photographic Retouching Material

A. Inherent Characteristics, Standards, and References

B. Brands and Specific Qualities

1. Schmincke Positive Retouching Colors (H. Schmincke & Co., Germany)

a) These paints are available in matte and glossy series and, in a broad sense, may be identified as gouaches. The colors are composed of pigments bound with gum arabic, dextrin, or "sugary substances." The gloss is controlled by the binder/pigment ratio **(correspondence with manufacturer, May 1992).** X-ray fluorescence analyses of these paints indicate the presence of iron, calcium, and copper in the brown-black and blue-black colors. (Detected elements are very similar to those observed in the Marabu Retouch Sets.)

2. Marabu Retouch Set

a) It is possible that these materials are identical in composition to the Schmincke Positive Retouching Colors. Further research is required.

3. Gamma Photo Retouch Kit

C. Lightfastness and Stability Characteristics

1. Many of these materials appear to be lightfast. The Schmincke Retouching Colors have been tested by the manufacturer and
compared favorably with the British Standard Blue Wool Scale (BS 1006).

2. In 1984, colorants from both the Marabu and Gamma Retouch Kits were exposed to 96 hours in Sunlighter II at the Library of Congress. (Twenty-four hours in Sunlighter II are equivalent to approximately 9 hours in a standard fadometer.) No perceptible change was noted in these materials.

D. General Observations, Techniques, and Special Applications

1. Many of these photographic retouching sets are most suitable for inpainting of modern black-and-white photographic materials. The glossy series often works exceptionally well for the inpainting of glossy contemporary black-and-white photographs.

2. The opacity of these paints combined with their increased granularity (compared with watercolors) makes them difficult to use in situations in which translucent effects are required.

3. These paints can be combined with watercolors (to modify tonality) and/or with gelatin or gum arabic to improve gloss. Modification of tonality is often required because the palette is preselected to reflect silver gelatin developing-out photographic prints in excellent condition.

4.5 Coating and Additives

A. The surface character of an inpainted area may be further modified by the local and controlled application of gelatin, gum arabic, methyl cellulose, acrylic resin, or acrylic dispersion solution.

B. Coatings must be selected very carefully to ensure their stability, chemical compatibility with all components of the photographic material, and removability if necessary.

C. Retouch Methods Co., Inc., manufactures a gum arabic-like material called Wondersol. This solution is often used by retouchers in an airbrush to "seal" each layer of airbrushed retouching and is also added to the gouache itself to assist in its flow. According to the manufacturer, it consists of gum arabic, methanol, water, and a preservative (Moldall). Everything goes into a suspension and the mixture is allowed to settle for 6 months. Undissolved gum arabic is skimmed off the top of the solution before it is packaged in a plastic jar fitted with an eyedropper lid. Use of this material may be considered to increase gloss on finished inpainting (Maxson). This material may be hazardous to health.

4.6 Treatment Variations

4.6.1 Mechanical Surface Manipulation

A. Gloss may be further increased by gentle, localized burnishing with an agate or Teflon burnisher, or a stainless steel dental tool.

B. Burnishing through silicone-release polyester film or paper may yield additional control and higher, more uniform gloss.

C. Rapid, light, and careful buffing with a cotton ball or swab may increase gloss (Messier).

D. Care must be taken that the original surface character of the photograph is not locally modified. Edges of a loss may appear highly burnished in raking light as a result of this type of modification/manipulation.

4.7 Special Considerations

4.7.1 Silver Mirrored Surfaces

A. The material that most mimics the way light is reflected from a mirrored surface is graphite. Graphite smudges very easily. When coated or used in a binding medium, graphite loses its reflective characteristics. Graphite may be appropriate for small scratches or losses but should probably be avoided for large areas (Luxner).

B. Iridescent and interference pigments are generally titanium dioxide coated mica particles and tend to be light stable. They are most often available within acrylic emulsions, but the pigment itself can be mixed with any binder. PAT testing on Golden Interference pigments showed no reactivity with photographic materials. The iridescent pigments work better than the interference pigments. In terms of color, interference colors tend to be too color-specific. The drawback to these materials is that they are consistently shiny, regardless of viewing angle, whereas a mirrored photograph varies in reflectance depending on the angle of light (Luxner).

C. "Silver" gouache, a metallic silver dry pigment, cake, or ink, may be added to watercolors to further modify and create a mirrored effect (Wagner).

4.7.2 High-Gloss Surfaces

Reproducing high gloss in inpainted areas of photographs can be achieved by utilizing coating materials in combination with inpainting medium or in a separate application (Gillis).

A. The manipulation used for achieving gloss on an insert is often unacceptable for use as a technique in areas adjacent to an inpainted loss.

B. When several layers of coatings are necessary to achieve sufficient gloss, there is a problem with build-up higher than the surrounding areas. The addition of a coating may shift the final color and must be compensated for during inpainting.

C. The mixing of coating materials into the inpainting medium seems to provide a better solution than coating. When combining medium with coatings, however, the compatibility of medium and coating becomes a factor for consideration in choice of both materials. For example, Soluvar provides a good coating, but it is not completely miscible with water-soluble inpainting materials.

1. Schmincke Retouching Colors (gloss) yield good results when used alone.
2. Possible combinations:
    a. LeFranc and Bougeois Restoration Colors and Soluvar
    b. Magna paints and Soluvar
    c. Watercolor and gum arabic
    d. Watercolor and gelatin
    e. Magna paints and Arkon P-90

D. Materials that can be employed to heighten gloss (as coatings and/or mixed into media) include gelatin, methyl cellulose, gum arabic, acrylic resins, acrylic dispersions, and Arkon P-90.

1. Most of these materials have been discussed above.

2. Arkon P-90 is a hydrogenated alphamethyl styrene polymer resin with a low molecular weight. It is soluble in a variety of solvents. Experiments have been successful using Arkon P-90 in shellsol and petroleum benzine. Shellsol requires a longer drying time, whereas petroleum benzine decreases the necessary drying time.

E. To achieve evenness of gloss, drying inserts under weight with silicone-release Mylar can cause a problem by either spreading the coating farther than the inpainted area and overlapping the original surface, or by not spreading it evenly enough over the inpainting. A ring or trough may be created, which only serves to call further attention to the inpainting than had it been left matte.

F. Barriers may affect gloss, but limit them to compatible materials. Methyl cellulose and PolyVinyl Acetate AYAA in ethanol are promising barriers. Although PVA AYAA in ethanol does not introduce water into the system, it limits inpainting materials that adhere. Preliminary experiments appear to indicate a higher gloss is noticeable when methyl cellulose was used as barrier.

4.8 Case Studies

A. During preparation for the retrospective exhibition Lisette Model (National Gallery of Canada, 1990), it was observed that nearly all of Model's prints showed corrective retouching of low-density images of particles, fiber debris, and scratches that had been printed from the negatives. Research showed that Model was concerned that her prints be retouched as a finishing procedure and that she had employed many people as retouching technicians over the years. Nevertheless, much of the retouching work observed on vintage Model prints was inexpert, incomplete, or faded. In a limited number of cases, the print chosen for the exhibition had not been retouched at all, despite the presence of many of the printing imperfections noted above. The organizing curator wished to have these imperfections suppressed in a number of the exhibition prints. A preliminary selection of works to be treated in this way was put together by the curator and reviewed by both the curator and a conservator; comparisons between prints within this group and with prints that had been satisfactorily retouched at the time of production helped to clarify the selection criteria and narrow the list. These comparisons were made under exhibition-type illumination, and specific "spots" to be retouched were discussed and decided upon. The main criteria were, (1) a desire to do as little additional retouching as possible while (2) suppressing imperfections that were distracting or that interfered with appreciation of the print image when viewed at a normal viewing distance. The actual retouching was done out with watercolors over a gelatin separation layer. Records of added retouching were produced on a photocopied reproduction of the print image (McElhone).

B. An extremely matte silver gelatin developing out print (Bernice Abbott c 1953) exhibited small losses in its emulsion. These damages were distracting, and it was determined that cosmetic treatment would be undertaken. The losses were coated with Soluvar Matte Varnish diluted with naphtha. Damages were then inpainted with Carb-Othello pencils (warm silver gray, ochre, and olive green) carefully blended with a small cotton swab. These inpainted areas remain readily reversible in naphtha (Brown).

C. The following is a preliminary attempt at compensation of a small loss of emulsion in a shiny black area on a silver gelatin photograph.

A gelatin solution (approximately 2%) was poured onto Mylar and allowed to dry. The dry gelatin film was peeled from the Mylar. Schminke Retouching Colors that matched the area surrounding the loss were applied to the non-shiny side of the film. The loss on the photograph was isolated with methyl cellulose and allowed to dry. The loss area was brushed with a minimal amount of water, and the colored film was placed shiny side up (paint side down) on the loss. The resultant compensation was very successful and merits further investigation (Andrews).

D. An Ansel Adams mural photograph measuring 48" square was brought to the Northeast Document Conservation Center for treatment. It was a black-and-white photograph of Half Dome and the Merced River in Yosemite National Park, dating 1961. It was adhered to hardboard (i.e., Masonite) with a solvent-based adhesive. As a result of having been glued to the sheet of hardboard, the photograph developed an extended network of cracks in the emulsion, which, in some areas, were severe enough to reveal paper fibers. The photograph was removed from the hardboard and remounted onto a modified

Japanese panel. Completion of the treatment required extensive inpainting along the cracks in the emulsion. Watercolor has always been a primary medium for inpainting and usually gives satisfactory results. However, if one attempts to recoat a photograph with a spray coat (for example, of gelatin) a color shift often occurs as the retouching is saturated, making it incompatible with the surrounding areas.

To avoid such alterations in tone, the conservator may try dry pigments, particularly if the principal tone is black or a variation thereof. Dry pigment can be used in a manner similar to watercolor. It is applied by brush, using either water or ethanol. The excess pigment on the photograph's surface can be wiped or brushed away, leaving the pigment only in the fissures. The dry pigment often dries matte, but if a final coating is to be applied, one will find that the resulting saturation of the dry pigment matches the emulsion surface reasonably well without a significant alteration of tone (Lee).

E. A very large Polacolor ER (approximately 7.5' x 3.5') photograph was treated for a 14-inch tear. The tear was mended with a strip of Japanese paper applied to the verso with Lascaux 360 HV adhesive. Because of the extreme sensitivity of the dye layer to moisture and concerns about reversibility, the tear was inpainted with dry pigments scraped from pastel sticks with a scalpel. This procedure was performed under a binocular microscope to insure that the pigment was applied only to the paper fibers exposed by the tear and that no residue was left on the surface of the print. The pigment particles were manipulated into place with a fine brush. By no means did this treatment achieve an illusionistic cosmetic effect. Because there are two layers of polyethylene in Polacolor prints, the tear was a very clean split. No attempt was made to fill the tear or match gloss. However, due to the large size of the print, the inpainting did achieve a visual consolidation of the image (Messier).

F. Unbleached white acrylic emulsion paint has been successfully used to retouch a large group of albumen prints. It may require modification in tone, but it acts as a good base for subsequent inpainting (Albright).

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1.1 PURPOSE OF EXHIBITION GUIDELINES FOR PHOTOGRAPHIC MATERIALS

1.1.1 Maximize the chemical and physical stability of the object while on display and during transit.

1.1.2 Minimize changes in the image, binder, and support from light exposure or other exhibition-related factors.

1.1.3 Create aesthetic and safe displays that allow photographs to be viewed in a manner that is satisfactory to the viewer and safe for objects.

1.1.4 Facilitate informed decisions by custodians about exhibition and loan policies as applicable to photographic materials.

1.2 FACTORS TO CONSIDER BEFORE EXHIBITION

1.2.1 Purpose and focus of exhibition

Identify the purpose and focus of the exhibition, such as didactic, commemorative, social, or aesthetic. Identify the nature and size of the intended audience.

1.2.2 Type of object

Identify the process and construction (final image material, binder, support) and the generation (original, vintage, modern, contemporary, unique, or facsimile) of the items considered for display. A consensus on definition or use of the terms used to designate generation does not currently exist. See Orraca (1992) for further discussion.

1.2.3 Format of object

Identify the format (print, mount, case, album, book, panorama, oversize, etc.): Examples of large format, oversize, multimedia, or constructions may not be exclusively considered photography.

1.2.4 Condition of object

Determine the feasibility of exhibiting an item. Consult previous examination and condition reports and photographic documentation to assess current condition and detect changes.

1.2.5 Exhibition history of object

Review the previous exhibition frequency, duration, and light level exposure of items through in-house tracking systems such as computer software or library-type sign-out sheets, conservation assessment reports, registrar files, and exhibit catalogs. Use exhibition history and consultation with curators to project exhibition demands into the future. Maintain up-to-date and detailed exhibition records.

1.2.6 Duration and number of venues

Determine recommendations for upcoming exhibitions by considering the exhibition history and projected future demands, along with other issues noted throughout this section. Compromises may be required to satisfy the demands of both preservation and exhibition.

1.2.7 Environmental conditions (all venues)

Evaluate the environmental conditions at each venue through facility reports and site visits to confirm acceptable conditions will be provided. Environmental conditions to check include, but are not limited to, light levels, temperature, relative humidity, airborne pollutants, and insect and pest mitigation. Stable, consistent environmental conditions are the most important factors in protecting photographic materials for future generations.

1.2.8 Consequences of condition change

Identify what affect exhibition conditions might have on the photograph and the consequences of condition change on the cultural and historical record.

1.2.9 Use of surrogates and facsimiles

Determine whether the use of surrogates is appropriate to the exhibition goals. Preserve original materials by exhibiting duplicates for long term and permanent displays and when a generic image of a person, scene, or event is needed to illustrate a point in an exhibition.

1.3 EFFECTS OF EXHIBITION ON PHOTOGRAPHIC MATERIALS

Photographs are created to be viewed by present and future generations. Later generations have attached importance to particular photographs, giving rise for the need for protective measures that promote the longevity of the material. In any exhibition, especially multi-venue exhibitions, there are unknown elements posing risks for which only a limited number of precautionary measures can be made. Irreversible chemical and physical damage that will alter the perception of a photographic item for future generations can result from exhibition duration or frequency and from movement of an item from one geographical location to another. Loss of aesthetic and historic information can result. It is advisable to monitor the changes and damages during exhibition in order to limit damage and reduce situations that have potential for damage in the future.

1.3.1 Effects of visible and ultraviolet light

Light damage is cumulative and permanent. Light exposure causes both fading and darkening. Photographic materials may be returned to dark storage for a period after exhibition. Although termed a "rest period" implying a restorative or recuperative effect on photographic materials after light exposure, restoration does not occur because light damage is not reversible. Periods of "rest" in between periods of display only ration the useful life of photographs between present and future generations.

1.3.1.1 By type of print

Very early photographic materials may not be suitable for exhibition. A photogenic drawing of a piece of linen fabric made by William Henry Fox Talbot, possibly around 1835, darkened by printing out within five weeks of exhibition (5 footcandles (fc), 53.8 lux (lx) tungsten source; 8 hours per day for 35 days while under UF-4 Plexiglas®). The climate was 70°F±2° (21°C) and 50%±5% relative humidity (Reinhold 1993a and 1993b, 91-92; Ware 1994, 47). Even monitoring of these types of photographs with densitometers can cause localized "fogging" and darkening. "The light sources in commercial reflectance densitometers are very intense (in the order of [10,000-15, 000 fc] 100-500 kilolux) and may cause a significant darkening of the small, but visible area of illumination (usually about [3/8 inch] 5 mm in diameter) *during the time of taking a measurement.* The use of finely graduated stepped gray scales on which are recorded the steps corresponding to key areas of images: the estimate would be made simply by visual comparison" is further suggested by Ware (1994, 55-56).

The worse the condition of the photograph, the less it can tolerate further degradation. Kodak's charting of light fading indicates that there is little change in the early life of a photograph, but that change increases with time. However, upon exposure, pristine albumen prints visibly fade more than already faded albumen prints. "The rate of image deterioration in [photographic prints] is closely related to their condition. Without exception, the prints in better condition showed more density change than those in poor condition. Platinum and palladium prints have a reputation for extreme stability, but [one palladium print that was exhibited for nine weeks] yellowed considerably in the middle tones and shadows. One might assume the change is a yellowing of the paper base due to the acidic nature of the process, but the absence of highlight yellowing tends to contradict that notion" (Severson 1987, 135). Yellowing might be the catalytic effect due to the action of light, in which palladium causes faster yellowing of the paper support in image areas than in non-image areas.

The iron compounds that constitute cyanotype images may be faded by light exposure. This fading may be partially reversible by dark storage (Reilly 1986, 43), but that is not always possible nor can reversibility be infinitely cyclical. Therefore, the phenomenon of reversal should not be assumed or used as a basis for increasing exhibition light levels (see section 1.4.1.3.2.2).

Properly processed image silver is not directly affected by ultraviolet light exposure. However, residual silver halide, such as that present in unfixed or partially fixed prints, remains light sensitive. Many of the silver-thiosulfate and other silver complexes that accumulate in poorly washed silver prints can be photo-oxidized, causing staining or further reactions. The factors (high relative humidity, high temperature, oxidizing chemicals, and light) affecting oxidative-reductive deterioration of image silver have been reviewed by Hendriks (1989, 645-50). Some products of photo-oxidation of organic components may oxidize metallic silver (Eastman Kodak 1985, 108; Reilly 1986, 103). Silver ions, produced by the action of moisture and oxidizing agents, may be reduced by light exposure (Eastman Kodak 1985, 84).

1.3.1.2 Coatings

Organic coatings tend to deteriorate, craze, crystallize, darken and yellow from light exposure. 19th century photographs may have various types of organic coatings including polymers derived from cellulose (collodion), natural water-soluble polymers (polysaccharides such as gum arabic), proteins (gelatin, albumen, casein), natural resins (Canada balsam, copal, dammar, mastic, rosin, shellac), beeswax, drying oils (such as linseed), essential oils (such as lavender oil), and hydrocarbons (paraffin wax, rubber, caoutchouc). For example, early albumen prints with watercolor retouching may have first been coated with a base coating of ox gall, gum arabic, alum, alcohol, or other materials (Waldthausen 2003b). In addition, uncolored ambrotypes, tintypes, and autochromes are manufactured with varnish and lacquer.

Synthetic coatings made from modern polymers may also be present in the construction of a photograph. Polymers may darken (becoming gray or yellow), cross-link, and craze caused by light exposure. Inkjet dye prints may be coated or laminated with an ultraviolet protectant layer to protect the light sensitivity of the colorants. Some black-and-white Polaroid® prints are stabilized with a proprietary coating. The light stability of synthetic coatings used on prints is not well characterized in photographic conservation literature. Polaroid Corporation (1983, 33) additionally recommended for its products the application of print lacquers, such as McDonald Photo Products, Incorporated's proprietary product, Pro-Tecta-Cote™, to protect against physical damage such as fingerprints and abrasion.

1.3.1.3 Color dyes and retouching

Color stability depends on the nature of the dye (Waldhausen 2003a). Organic dyes comprising the photographic image, or present as filters or sensitizers, are subject to light-induced changes in density (Giles et al. 1973; Wilhelm 1979); ultraviolet radiation is particularly active in this respect. Light exposure induces changes in the density of dyes that results in a color shift or fading of the image (Schwalberg et al. 1990). "Black-and-white" chromogenic prints and C-41 process black-and-white prints will fade because of their color dye construction. Dyes used to tint the paper supports or binders of some albumen prints are extremely fugitive (Burgi 1982; Reilly 1986). Optical brighteners introduced in photographic manufacture in the 1950s are also fugitive and can discolor upon exhaustion (Messier 2000; Mustalish 2000).

Monochrome and color prints have frequently been heightened, retouched, or painted overall with a variety of media that may constitute the most fugitive components of a print. The black color of a paint or ink is no guarantee of its permanence as it may be composed of several fugitive colorants.

Daguerreotypes, ambrotypes, and tintypes with applied color, even the most vividly colored images, have very little pigment in comparison to pastels, watercolors, or oils, which means there is the smallest margin before visible fading can be recorded. Uncolored daguerreotypes are not particularly light sensitive, but the materials of the components comprising the case and daguerreotype package may be far more sensitive than the image (see section 1.3.1.6).

Receptor coatings can be titanium dioxide (Jürgens 2000, 63). Some cationic fixing agents applied to paper can be detrimental to magenta dye chromophores (Lavery, et al. 1998, 329). Inkjet dye-based images and chromogenic prints are generally among the most light sensitive color processes (Waldthausen 2003). The light-fastness of inkjet dyes will be improved if the substrates on which the dyes are printed do not generate oxidants, reductants, or radicals inherently (Gregory 2000, 50). Despite the complications, dyes used in inkjet printers are steadily improved, as the industry is aware of consumer and photographic artist's concerns for light fastness and product longevity.

1.3.1.4 Binders

Proteins are subject to deterioration from visible and ultraviolet light. The albumen binder offers some protection to the photographic image from the damages of light (Moor and Moor 1992, 195); however, albumen itself is subject to bond-breaking and photo-oxidation by ultraviolet light (Messier 1991, 134), causing yellowing. Albumen prints also yellow from an internal protein-sugar chemical reaction, known as the Maillard Reaction, that occurs when albumen is subjected to light radiation in the presence of moisture from humidity (Reilly 1986, 35). Gelatin, less sensitive than albumen, may be yellowed and embrittled by prolonged light exposure; however, this deterioration is unlikely to happen at museum light exposure levels (Reilly 1986, 103; Eastman Kodak 1985, 84). Lavédrine and Gann suggest that prolonged light exposure can deteriorate the collodion binder causing cracking (Waldthausen 2003a, 3).

1.3.1.5 Supports

Paper supports may lighten or darken and become weakened by light exposure, principally from ultraviolet. Lignin-containing papers may discolor (Reilly 1986, 103; Michalski 1987, 10). The yellowing of paper can alter the perceived color of the photographic media. Associated photographic support materials like album pages or colored mounts, such as the Pictorialists used, may be constructed of poor-quality and extremely light-sensitive paper.

Gelatin emulsions will absorb most of the incident ultraviolet energy, and a baryta layer will block most incident light from reaching the paper support. Since the 1950s, the composition of photographic papers manufactured by Kodak and Ilford may contain a portion of wood pulp and optical brightening agents (Messier 2000). The optical brighteners are exhausted through light exposure. A print with an exhausted brightener will appear dull (darker) overall.

"Crack propagation" of the poly (ethylene) layer of resin coated papers is caused by active oxidants forming internally in the titanium dioxide layer (the opacifying and reflecting layer below the image) when the photograph is exposed to light with an ultraviolet content (Parsons et al. 1979, 111-112). Poly (ethylene) in early resin-coated papers is particularly subject to crack propagation. These oxidants also attack the silver image, resulting in reduction-oxidation (redox) blemishes, mirroring, and orange colloidal silver (Roth 1999; Ctein 1998a, 1998b). Kodak incorporated stabilizers into the paper core around 1977. "Over time the stabilizer diffuses into the adjacent poly (ethylene) layer, thereby significantly increasing their resistance to embrittlement and cracking" (Wilhelm 1993, 128). Early resin-coated prints should be exhibited with caution.

The support effects the light-sensitivity of each unique inkjet print (Lavédrine 1997). Commercially available inkjet printers originated in 1994 and early dye inks were very light fugitive as the machines were designed for short-term office use (Wilhelm 1999).

Irreversible yellowing of poly (methyl methacrylate) (PMMA) comprising face-mounted photographs may occur. Exhibition lighting sources should be free of ultraviolet light.

1.3.1.6 Cases (for cased photographs)

Daguerreotype, ambrotype (positive collodion), and tintype cases are covered with dyed leather or paper. There are dyed textiles inside, as well as glass. Some cases are made of a more durable thermoplastic ("union cases"), but some have a lacquer finish with coloring and inlaid mother-of-pearl, which can be heat and light sensitive. Light levels need to be high enough to make the daguerreotype image easily viewable, but low enough to pose no undue risk to the textile linings and to avoid heat buildup under the cover glasses.

Heat buildup should be a concern due to the enclosed nature of the daguerreotype package, which traditionally consists of a brass foil preserver, a paper tape seal, a cover glass, a brass mat, and the daguerreotype plate. Heat can drive mechanisms such as glass deterioration. Light can also drive chemical deterioration of residues left on the plate by some cleaning methods (Barger and White 1991; Barger and Edmondson 1993).

1.3.2 Effects of extremes or cycling of temperature and relative humidity

Rapidly changing temperatures can cause moisture to form on the interior of glazing in a frame. This situation is most likely to occur during transportation of photographic materials from venue to venue. Sand and salt from coastal area waters, and snow and ice suppression can also affect the humidity levels in a building environment.

1.3.2.1 By type of print

Salts are hygroscopic in nature and therefore sensitive to changes in the relative humidity (Moor and Moor 1992, 196-197). "Nineteenth century processes have shown considerable shifts in density as a direct result of [changes in] relative humidity and equilibrium moisture content [EMC] levels in both exhibition and dark storage environments" (Moor and Moor 1992, 197).

1.3.2.2 Coatings

Coating materials craze, darken or yellow, and bloom from extremes or cycling in temperature and relative humidity. 19th century photographs may have various types of organic coatings including polymers derived from cellulose (collodion), natural water-soluble polymers (polysaccharides such as gum arabic), proteins (gelatin, albumen, casein), natural resins (Canada balsam, copal, dammar, mastic, rosin, shellac), beeswax, and oils (such as linseed), and essential oils (such as lavender oil), and hydrocarbons (paraffin wax, rubber, caoutchouc) that are susceptible to damage from environmental conditions. For example, early albumen prints with watercolor retouching may have first been coated with a base coating (ox gall, gum arabic, alum, alcohol, or other materials) (Waldthausen 2003b). In addition, uncolored ambrotypes, tintypes, and autochromes are manufactured with varnish and lacquer. Coatings of natural water-soluble polymers (polysaccharides such as gum arabic) can easily soften in high humidity conditions. Synthetic coatings made from modern polymers may also be present in the construction of a photograph. Polaroid Corporation (1983, 33) recommended for its products the application of print lacquers, such as McDonald Photo Products, Incorporated's proprietary product, Pro-Tecta-Cote™, to protect against physical damage such as fingerprints and abrasion. At present, the effects of temperature and humidity on synthetic coatings used on prints are not well characterized in the photographic conservation literature.

1.3.2.3 Color dyes and retouching

Dyes used to tint albumen prints can fade in environments with high relative humidity (Reilly 1986, 37-38). Dyes used in inkjet printers can be very soluble in water. Blurring may result from elevated humidity and heat. Research by Robb (2000) on Iris, continuous area-modulated inkjet, samples indicate that the magenta dye is most sensitive to moisture. Begun in 1994, first generation inkjet dyes were anionic-water soluble dyes (Gregory 2000, 50). Second-generation inkjet dyes were novel dyes. Alkaline conditions made the ink water-soluble; acidic papers greatly improved water fastness. In the late 20th c. organic pigments were being substituted for dyes in inkjet printing. Environmental conditions should be at least 71°F/21°C and 40-50% RH during exhibition.

1.3.2.4 Binders

High humidity drives many deleterious photochemical reactions including reduction-oxidation (redox) reactions in silver gelatin systems (Lavédrine 2003, 160). Keeping "the relative humidity below 60% will discourage biological attack (fungus and mold) on gelatin materials" (Hendriks et al. 1991, 404). Low relative humidity levels can cause cracking and flaking in gelatin-based emulsions and cracking in albumen photographs (Reilly 1986, 35).

1.3.2.5 Supports

Fluctuations in temperature and humidity can alter the dimensions or the flatness of photographic materials, "accelerate degradation, facilitate migration of oxidated acidic complexes to the surface, allow absorption of atmospheric pollutants and give rise to internal physical stress and distortion in an already fragile stratigraphy" (Moor and Moor 1992, 196 to 97). The poly (ethylene) layer in early resin-coated papers are susceptible to cracking from normal ranges of cycling humidity levels, especially if exposed to light with ultraviolet content or for long periods of time (Parsons et al. 1979, 113). "High humidity levels accelerate chemical reactions of image silver with residual processing chemicals and enable the formation of acidic compounds in paper in the presence of oxides of sulfur or nitrogen" (Hendriks 1989, 646). High relative humidity levels can promote biological growth, and thus, staining, in paper supports (Lavédrine 2003, 160).

1.3.2.6 Cases

Components of a sealed daguerreotype package are glass and metal. Therefore it might be best to try to keep the general relative humidity no higher than 50%, and possibly as low as 40-45%. These levels will reduce the potential for glass deterioration or condensation inside the package but will be high enough not to desiccate the leather, wood, textile, and paper components of the case and daguerreotype package. Similar concerns exist for cased ambrotypes (positive collodions) and tintypes.

External lighting sources (radiant heat) can create an imbalance between the internal and external temperature and relative humidity of photographs on display, in essence forming a greenhouse effect within cased and framed photographs (Ritzenthaler et al. 1985; Reilly

1986; Moor and Moor 1992). Another opinion is that heating caused in this way (too much infrared absorption from an illuminant) will drive down the relative humidity in any air space contained within the package but will not significantly affect the equilibrium moisture content of the photographic materials. In a frame, since both the matboard and the photograph will be losing water to the air, the relative humidity will not change very much. However, the photographic materials will lose a small amount of water. A significant drop in temperature can lead to the formation of condensation in the package. Display cases will behave differently, depending on the amount of hygroscopic material within the enclosed space. For exposed photographic items in a display case, the change in equilibrium moisture content may be significant.

1.3.3 Effects of airborne pollutants (oxidants, organic acids, and volatile organic compounds)

Airborne pollutants include, but are not limited to carbon dioxide, hydrogen sulfide, nitrogen oxides, ozone, and sulfur dioxide.

Sulfur oxides (SO_x) and nitrogen oxides (NO_x) from the combustion of fossil fuels (found in automobile exhaust and smoke from factories, for example) can cause fading and loss of contrast in silver-based photographic materials. Both form acidic gases and thus can damage various binder and support layers. Sulfur dioxide (SO_2) is a reducing agent, which in the presence of oxidants will contribute to the oxidation-reduction deterioration of silver image material. These forms of silver image deterioration can be observed as silver mirroring, yellowing of the binder, and fading of images, including loss of highlight details. Hydrogen sulfide (H_2S), an industrial pollutant of outdoor air, is an acidic gas that can cause yellowing and fading of silver image materials, and, when oxidized, reacts with moisture vapor to form sulfuric acid, which can damage cellulose substrates and affect binder layers. Sources of sulfur off-gassing include deteriorating rubber that can be found in some adhesives, rubber bands, and gaskets on cases used for transport, exhibit, and storage. Commercially available cleaning solutions and floor waxes can contain various volatile organic compounds that can be corrosive to photographic images.

Ozone (O_3), contributes to the formation of peroxides and free radicals, which cause fading and discoloration of photographic images and damage support and binder layers by oxidation attack. Sources of ozone include smog in external air, HVAC systems equipped with an ozone purifier, and office copying machines.

Oil-based paints, as they cure and dry, give off peroxides as well as acidic by-products that contribute to fading and discoloration of photographic images; thus these paints should not be used in exhibit (or storage) areas.

Some cardboards, woods, wood adhesives, cleaners, and bleaches can also generate peroxides. Ammonia (NH_3), sometimes found in cleaning products and in adhesives used to construct matboard, can cause fading of photographic images.

Organic acids, such as acetic (CH_3COOH) and formic ($HCOOH$), from formaldehyde ($HCHO$) can cause darkening of cellulose substrates and corrosion of some metals. Acetic acid can be generated from wood, wood adhesives, and paint. Drying oils, oil-modified, and oil-based paints give off acids, aldehydes, and peroxides. Alkyd and oil-based enamels will off-gas organic acids, aldehydes, and carbon dioxide if the temperature and cooking time are insufficient for proper attachment to the substrate. Formaldehyde gases can be generated by wood, plywood, and particleboard adhesives, insulation, and carpeting. Acetic acid gas is also a deterioration by-product of cellulose acetate base film materials and can be detected by its vinegar smell often before physical deterioration is visible to the unaided eye.

Deterioration from build up of organic acids is generally of greater concern during long-term storage than during short-term exhibition.

Inorganic acids (referred to as "mineral acids" in NISO 1999) include nitric acid (HNO_3), sulfuric acid (H_2SO_4), hydrochloric acid (HCl), and phosphoric acid (H_3PO_4). These may not be air pollutants per se, but, as noted, nitric, sulfuric, and hydrochloric acids can be formed in reactions between atmospheric moisture and air pollutants and other off-gassing components within a gallery space or exhibit display case. Some acids, such as nitric and sulfuric, are also strong oxidizers.

Particulate materials such as dust, grit, mold spores (conidia), and combustion products (smoke and soot) can scratch soft emulsions and discolor paper-based photographic images. A tobacco-free environment is recommended, as even small amounts of tar and nicotine stain coatings, binders, and supports.

Wilhelm (1993, 577, 576-624) cautions against long-term framing of black-and-white prints with plastics (i.e., Plexiglas glazing) because of the possibility of trace amounts of peroxides and other substances. Peroxides are aggressive oxidizers, as noted previously. There is insufficient long-term data on oxidation generated by long-term framing, however; resin-coated (RC) papers have the potential to generate peroxides during display.

Resin-coated (RC) prints are thought to be more susceptible to the effects of airborne pollutants because of what is referred to as the "sump effect"; that is, with RC papers, atmospheric pollutants can go in through the front, emulsion side, and have nowhere to go, as the polyethylene coating on the paper support effectively seals it off. However, with fiber-base prints, the paper support can act as a "sump" to take up the pollutants, away from the emulsion and image layer (Ctein 1998).

Though not quantifiably measured, several silver-based prints (from between 1920-1945) that already had silver mirroring in the darks and around the edges, seemed to develop more iridescent sulfiding after returning to the Metropolitan Museum of Art from a traveling show lasting a year and a half. While there are many factors that might be contributing, it was intuitively felt by then staff conservator, Betty Fiske, that the change was a result of the closed microclimate over such a long period of time. Fiske believed the issue merited an alert until various factors affecting photographic materials are studied and more fully understood.

Color print materials, being more susceptible to light damage and the effects of temperature, may demonstrate less reaction (relatively speaking) to airborne pollutants. The reactions to airborne pollutants, including fading from exposure to oxidants, definitely occur but may not be as readily discernible because the deterioration reactions from the effects of light and of temperature occur more quickly by comparison (Zinn et al. 1997).

Face-mounting a photograph to a rigid transparent support, such as to poly (methyl methacrylate) (PMMA), has become a popular mounting method for large, oversize photographic prints amongst contemporary photographers. In 2002, one brand, Diasec®, advertised on their website mounting with acrylic and poly (vinyl chloride) (PVC) materials of varying gloss. The mounting process and materials involved have been described in recent publications (Pénichon and Jürgens 2001b, 2002a), and the long-term stability of these composite laminates is being tested (Pénichon and Jürgens 2002b). Face-mounted photographs on PMMA sheets may eventually craze because of the solvents contained in the silicone rubber adhesive formulation or in proprietary PMMA cleaners.

1.4 STANDARDS, GUIDELINES, AND RECOMMENDATIONS

1.4.1 Light exposure: Levels, duration, and wavelength of light

Currently, there is no agreed upon standard for illumination type, illumination level, or duration of exhibition.

1.4.1.1 History of standards

The standards prevalent in the conservation literature and within institutions follow established guidelines for light sensitivity of media (pigments, inks, dyes) and supports (paper, animal skins, textiles, metals) obtained through research in other disciplines. It is accepted opinion that photographic materials are sensitive to light exposure and environmental factors, as are composite objects. Research specifically on photographic materials has increased in the last few decades in the private sector in settings not attached to major manufacturers of photographic materials.

1.4.1.2 Current guidelines and recommendations for light exposure levels

Light exposure should be kept to the minimum level that will both safely illuminate the photograph and provide adequate visibility to the viewer. Ultraviolet radiation should be reduced as much as possible. A maximum limit of 75 microwatts per lumen is accepted in exhibit lighting for general collections material. Ultraviolet radiation will vary by light source. The appropriate light source will depend on the material displayed. The type of light, spectral distribution, intensity (illuminance level), duration, and distance of illumination (heat from the source) are all factors to be considered when exhibiting photographic materials. Accuracy of instrumentation is critical to monitoring. It is unrealistic to set any limits that cannot be measured with available equipment.

Organizations such as the American National Standards Institute (ANSI) and the International Standards Organization (ISO) regularly issue standards for the display and storage of currently produced photographic materials. As these complex systems become better understood and manufacturing processes become more refined, standards may change. Standards are based on newly produced materials. Despite similar chemistry, aged materials may respond differently to external conditions. It may not be suitable to use a standard based on current photographic materials when displaying historic, aged materials.

The National Information Standards Organization (NISO), Committee MM, drafted a standard for the exhibition of library and archives materials (Z39.79-1999) that included photographic materials. The NISO standard recommends a general light exposure of 4.6-9.3 fc (50 -100 lx) with reduced ultraviolet radiation and limited to 12 weeks exposure per year, with reduced light levels when exhibition areas are not in use. To obtain current standards, please refer to the standards organizations listed in section 1.8 for contact information.

1.4.1.2.1 Institutional guidelines and recommended standards

The following information was gathered by an informal survey beginning in 1995, augmented by compilers to provide references. Please consult individual institutions as necessary for current guidelines and recommended standards. Please note that 1 footcandle (fc) = 10.76 lux (lx). For ease, footcandles are often multiplied by 10 for lux. Light sources have below 50 microwatts per lumen for these guidelines.

Institution (In house publication date)	Print Type	Foot-candle	Lux	Considerations	Duration
National Gallery of Canada		5-15	53.8-161.4	Assessed individually for light sensitivity	Loans not to exceed 11 months
Museum of Fine Arts, Boston, MA (2000)	Most sensitive	5	53.8	Assessed individually for light sensitivity	3 months display, every 5 years, 57 months dark storage
Museum of Fine Arts, Boston, MA (2000)		5	53.8	Assessed individually for light sensitivity	3 months display every 3 years: 33 months dark storage
International Museum of Photography at the George Eastman House, NY		Below 10	Below 107.6		
Metropolitan Museum of Art, NY	color				Color, not more than 3-4 months every 5-10 years
Metropolitan Museum of Art, NY	albumen	4	43		
Philadelphia Museum of Art, PA		5	53.8	Exceptions up to 10 fc/107.6 lux on rare occasions	
National Gallery of Art, WDC (1998)		Max 5	Max 53.8		
Cincinnati Museum of Art, OH (1996)	19th c.	5	53.8	Assessed by type of photograph and individual condition	4-7 months per exhibit venue with 5 year dark storage
Cincinnati Museum of Art, OH (1996)	Silver gelatin	10	107.6		6-12 months per exhibit venue with 3 years dark storage
Cincinnati Museum of Art, OH (1996)	color	5	53.85		6-12 months per exhibit venue with 3 years dark storage
Art Institute of Chicago, IL (ca 1990s)		Max 10	Max 107.6	Assessed by type of photograph and individual condition	Maximum 12 weeks/3 months per exhibit venue
Humanities Research Center, University of Texas at Austin, TX	General illumination in gallery	7-10	75.32 – 107.6		
Humanities Research Center, University of Texas at Austin, TX	Light falling on specific identified item	5-7	53.8-75.32	Assessed by type of photograph and individual condition	
Legion of Honor, San Francisco, CA	Contemporary photographs	10	107.6	Assessed by type of photograph and individual condition	
Legion of Honor, San Francisco, CA	19th c., vintage, important	5	53.8	Assessed by type of photograph and individual condition	
J. Paul Getty Museum of Art, CA		Max 7	Max 75.32	Lower for sensitive materials. Tungsten light sources used	

Institution (In house publication date)	Print Type	Foot-candle	Lux	Considerations	Duration
British Library, UK (ca 1990s)	Paper-based	Max 10	Max 107.6	UV removed from light source	
Victoria and Albert Museum, UK (1988)		5	53.8		
National Trust, UK (1998)		5	53.8		

1.4.1.2.2 Artist's Comments

Some photographers have commented in writing and directly to gallery and museum personnel regarding preferred light levels for their work:

Ansel Adams (1950, 21): "The best gallery illumination, to my way of thinking, is a mixture of daylight and tungsten sources. Straight daylight illumination is perhaps too cold for general interior-display effect. I personally prefer to judge my prints with a light equivalent to that of north skylight (between the hours of 10 a.m. and 4 p.m. [16:00] in summer) with a white-card intensity reading of about 40 on the Weston meter".

Cindy Sherman: *Deterioration Series* chromogenic prints are printed dark with fully saturated colors. Her printer recommends display under bright lighting. When the images fade or deteriorate, Sherman feels the images can be reprinted.

William Wegman: Wegman specified that the light levels be 25-30 fc (269-322.8 lx) for his *Cinderella and Little Red Riding Hood* Polaroid prints. However, one institution displaying these prints determined that 12-15 fc (129.12-150 lx) would be adequate lighting for the color saturation of these prints.

Contemporary photographers using historic methods (sometimes called "alternative photographic processes") are aware of the discrepancies that different types and levels of illumination can have on the aesthetic look of their photographs. Photographers may request exhibition lighting to be similar to their studio lighting for optimum display.

1.4.1.3 Assessment approaches

1.4.1.3.1 Assessment by individual item basis

Before 1993, the National Archives and Records Administration (NARA), Washington, D.C., conservation staff discussed a ranking system for individual photographic materials based on internal factors of composite photographic processes. The proposal was to develop a "value-list" for each category of sensitivity. Items with large numbers or within pre-designated letter categories (e.g., A = highest risk) would equate to being more sensitive and prone to damage from display conditions.

For example, a conservator might wish to limit display of a 19^{th} century hand-colored albumen print in good condition because it is the collection's only pristine copy and has fugitive dyes. Alternatively, one could argue that display is permissible because the image, the binder, and the support are in good condition. The "value-list" approach would give the conservator a rating for each photographic item that curators, historians, and exhibitions staff might easily comprehend.

As with checklists for condition surveys of collections, however, it is hard to make complex and varied materials fit into a standardized formula. Material that is most at risk may have few "marks" indicating the extent of the risk, while another item that could be safely exhibited more often might come out of the equation looking as if it were a high-risk material. In addition, intuitive value judgments are necessary in each case.

1.4.1.3.2 Assessment by class of material

1.4.1.3.2.1 Assessment by type: Proposed Guidelines

1.4.1.3.2.1.1 Library of Congress

Draft guidelines for exposure levels were compiled for the Library of Congress, Washington, D.C, in 1991 and updated in 1996 and 2000 (Wagner with McCabe and Lemmen, with later additions within this chapter by reviewers Brown, Dune, Jacobson, Kennedy, McElhone, Pénichon, Reinhold, and Robb. Printed without additions in *Topics in Photographic Preservation,* 9, 2001.) This alphabetical listing is similar to ones developed for the Smithsonian Institution's collections. In these guidelines, decisions about the true light sensitivity of an object are made on an individual basis.

It is presumed that exhibition materials used have passed the Photographic Activity Test (ISO 14523:2000). It is also presumed that the light sources have ultraviolet and infrared content removed, relative humidity maintained around 45 to 50%, and air contaminants filtered out. Light sources that do not meet these specifications should be used at reduced exposure limits as damage from exposure is cumulative. The sample calculations are based on 10 hours of light exposure per day.

3 fc x 5 months [150 days] = 5 fc x 3 months [90 days] = 4500 fc-hours [48,420 lx-hours]
5 fc x 6 months [180 days] = 10 fc x 3 months [90 days] = 9000 fc-hours [96,840 lx-hours]

<u>EXTRAORDINARILY light sensitive: **Recommend displaying facsimiles ONLY**</u>
autochromes (color) and other early dye processes
experimental processes (e.g., unfixed salted paper prints)
stabilized silver gelatin prints

<u>VERY light sensitive materials: 3000-5000 fc-hrs (32,280-53,800 lx-hrs)/year maximum with all ultraviolet light removed from light source: Consider using facsimiles:</u>
all hand-colored, deteriorated, or poorly processed prints (fixer stains or smell)
albumen, printing-out process (pristine)
architectural plans or photo-reproductions (cyanotype [blueprint], brown lines, diazotype, Pellet prints, photostats, Vandyke brown)
carbon prints made of non-earth-based pigment or on poor-quality paper
cased objects where case, velvet, dyed leather, or silk is exposed (fugitive colors)
coated photographs (organic or unknown)
color photographs and processes (especially pre-1990)
computer-generated prints (including ink jet dye-based inks or poor paper support)
cyanotypes (blueprints) (variable; composition determines light sensitivity extent)
dye imbibition (Dye Transfer, color)
gum bi/dichromate (unknown paper, suspected poor-quality paper, or light sensitive pigments)
hand-colored photographs (all types)
modern ink inscriptions (e.g., felt-tip pens, ballpoint, purple manuscript)
mounts of colored paper, fabric (especially colored construction paper or dyed materials)
platinum, palladium, and mixtures with silver, with pink- or yellow-stained paper

Polaroid® and other instant processes
resin-coated supports (pre-1980, since 1950 optical brightening agents may be present)
salted paper prints, printing-out process
silver dye bleach (color, Cibachrome™ 1963-1991/Ilfochrome™ 1991-present)
tinted bases (e.g., blue or pink albumen or baryta layer)
transparencies (color, pre-1990)
Woodburytype (non-earth-based pigment or poor-quality paper)

<u>Light sensitive materials: 5000-10,000 fc-hrs (53,800-107,600 lx-hrs)/year maximum with all ultraviolet light removed from light source</u>
albumen printing out process
color processes (post-1900, at higher light for shorter duration)
Cibachromes/Ilfochromes™ (at higher light for shorter duration)
collodion printing-out process
gum bi/dichromate (more sensitive paper, but earth pigments)
gelatin developing-out process (includes pre-1980 resin-coated papers or contemporary papers with fugitive optical brighteners)
gelatin printing-out process
manuscript ink inscriptions
photomechanical prints with sensitive inks or poorer paper (photogravures, collotypes, carbro-carbon prints, etc.)
platinum, palladium, and mixed with silver on good-quality paper (less if discolored)
salted paper prints, printing out process (faded)

<u>Less light sensitive materials: 10,000-20,000 fc-hrs (107,600-215,200 lx-hrs)</u>
ambrotypes (positive collodions) without cases (good condition, no coloring)
carbon prints (good paper with carbon or earth pigment)
daguerreotypes without cases (good condition, no coloring)
gelatin-silver developing-out print on fiber-based paper (well-processed black-and-white, no hand coloring, no optical brightening agents)
gum bi/dichromate (good paper with carbon or earth pigment)
matte collodion, printing-out print (good condition, no coloring)
photomechanical prints with lightfast inks on good paper without hand coloring (photogravures, collotypes, carbro-carbon prints, etc.)
tintypes without cases (good condition, no coloring)
Woodburytypes (good-quality paper with carbon or earth pigment)

1.4.1.3.2.1.2 Centre de Recherches sur la Conservation des Documents Graphiques (CRCGD; Center for Research on the Conservation of Graphic Documents)

Based on his research, Dr. Bertrand Lavédrine (2003, 161, 163) recommends the following light levels and annual durations, assuming that all ultraviolet and infrared radiation have been eliminated from the light source and all display materials are of the highest quality:

<u>Category 1 (Particularly sensitive) not to exceed 1115 fc-hrs (12,000 lux-hrs) annually with a maximum illumination of 4.6 fc (50 lux):</u>
chromogenic development
color photographs
instant photography
19th century photographs

Category 2 (Very sensitive): Not to exceed 3903 fc-hrs (42,000 lux-hrs) annually with a maximum lumination of 7 fc (75 lux):
dye-transfer photographs
dye-bleach color photographs (Ilfochrome Classic)
resin-coated black-and-white photographs

Category 3 (Sensitive): Not to exceed 7807 fc-hrs (84,000 lux-hrs) annually with a maximum lumination of 14 fc (150 lux):
baryta paper black-and-white photographs
monochrome or pigment color photographs

Objects that are not very sensitive to light are recommended to have a maximum illumination of 28 fc (300 lux).

1.4.1.3.2.2 Assessment by type: Earliest 19th century photographs

Wilhelm (1993, 608 to 609) recommends that "salted paper prints (ca. 1840 to 1855) and albumen prints (ca. 1850 to 1895) never be displayed, even for short periods." Ian and Angela Moor (1992, 201) believe that the following original 19th century materials should not be exhibited until future research identifies "safe methods" (listed alphabetically):

- calotype (potassium bromide stabilized)
- chromatype (Hunt)
- chrysotype (Herschel)
- cyanotypes (pre-Pellet variant 1877, Herschel)
- direct paper positives (Fife, Talbot, Bayard)
- Energiatype (Hunt)
- Leucotypes
- photogenic drawings (stabilized sodium chloride-silver chloride, potassium bromide, or potassium iodide);
- salted paper print (sodium thiosulfate fixed)
- Talbot's processes without exception.

Ware's (1994, 55) conclusion from research of William Henry Fox Talbot photographs was "*most of the damage is likely to be done by visible light*" although ultraviolet radiation must be removed from any light source whether in storage or display areas. The variability of the material in question does not provide easy quantifiable solutions. "Exhibition under the customary 5 fc (53.8 lx) would appear to be out of the question; display under very low [1 fc (10.76 lx)] carefully filtered light, with proximity switching or a viewer activated curtain, would only allow about 30 hours of exhibition before the threshold exposure (limit) was reached" (Ware 1994, 55 to 56). Ware's test image was "fogged." His research suggests that "the threshold exposure lifetime (TEL) for chloride-fixed photogenic drawings is in the order of three hours, and this vulnerability to light may well be panchromatic, that is, sensitive in some measure to all wavelengths of the visible spectrum" (Ware 1994, 55-56). Research by Ware (1999) and McElhone (1993) indicates that cyanotypes can be exhibited safely for short periods of time at or under 5 fc (53.8 lx) using light with all ultraviolet radiation removed and in a deep mat to provide a large air space. The light stability of cyanotype prints is highly variable, as the light stability is dependent, in part, on the original chemistry of each print.

However, since these materials will be exhibited, over the objections of conservators, these recommendations should be used as a basic guideline to determine the longevity of display, the illuminance level and design, and temperature and relative humidity levels to be maintained. Another alternative is to make replicas and duplicates.

Duplicates with similar processes and at times, better processing, may be an option to display images prone to light fading or just too sensitive to display. (see 1.6.5 Rotation, replacement, duplication, and facsimiles.)

1.4.1.3.2.3 Assessment by type: Cased 19th century photographs

Daguerreotypes and other cased photographs (ambrotypes, also called positive collodions, and tintypes) were historically illuminated from the side by natural light from windows or by lamps on tables. Overhead illumination will descend across the polish lines, which are on a horizontal orientation to the plate, creating a haze of scattered light that can obscure 40% or more of the image. Daguerreotypes are best viewed with "single-source," directional light illumination coming from a 45° angle to the plate surface. This arrangement will allow the reflected light to pass to the side of the viewer; otherwise, only glare or a mirror effect will be seen. Fiber optic light systems are probably the optimum, but excellent results can be had from light piping as well. Other light sources can be very effective, but they may require a great deal of effort to achieve results more easily obtained with a fiber optic source.

Uncolored daguerreotypes, ambrotypes, and tintypes should be considered moderately light sensitive, but because of the auxiliary components that comprise the entire object, the standard restrictions regarding ultraviolet should be maintained. Auxiliary components include cases covered with dyed leather or paper, dyed textiles inside the cases, and glass covers. Some cases are made of a more durable thermoplastic, but some have a lacquer finish with coloring and inlaid mother-of-pearl, which can be heat and light sensitive. Light levels need to be high enough to make the daguerreotype image easily viewable, but low enough to pose no undue risk to the textile linings. The singular advantage to fiber optic lighting is the extremely high degree of control over where the light strikes. It is possible to focus a higher light level on the image, perhaps 10-15 fc (107.6-161.4 lx) and have less light striking the textile covering on the case lid liner.

Ambrotypes and tintypes come with many of the same components as do daguerreotypes, and therefore the same caveats apply. Heat and humidity probably pose a greater risk than does actual levels of illumination because these images commonly have at least one layer of a natural resin varnish. However, light levels should not exceed 10-15 fc (107.7-161.4 lx). Although it is rare for unvarnished images to be in any condition to be placed on exhibit, some have survived remarkably well.

1.4.1.3.2.4 Assessment by type: 20th century black and white developing-out prints

Hendriks et al. (1991, 438) proposed that black-and-white silver gelatin developing-out prints could be "safely exposed at illuminance levels between 500 fc (5380 lx) and 1000 fc (10,760 lx) provided there is clean air in the display area and both temperature and relative humidity are controlled and stable." Length of time was not specified. However, the thoroughness of processing, length of exhibit, and previous cumulative exposure history should also be considered in determining light exposure. Many conservators believe that 500 fc (5380 lx) is an excessive and unnecessary level of light exposure and continue to recommend light levels be kept between 5 and15 fc (53.8 and 161.4 lx).

1.4.1.3.2.5 Assessment by type: 20th century color photographs

Wilhelm (1993, 577) maintains that contemporary color prints "should be displayed with adequate illumination. There is no 'minimum' illumination level at which color print fading does not occur." He recommends approximately 30 fc (322.8 lx) of incandescent or glass-filtered quartz halogen illumination for archives, galleries, and museums and 45 fc (484.2 lx) for commercial or private home illumination for contemporary color photographs. The length of exhibition is not defined. Hendriks et al. (1991, 440) agree, stating, "in order to perceive colors in photographs on display, an illuminance of 30 fc (322.8 lx) is recommended." They recommend shortening the duration of exhibitions to compensate for higher light levels. Wilhelm (1993, 61-100, 230) further notes that because of reciprocity failure, not all color photographic dyes fade at the same rates. His accelerated aging results indicate that for some color photographic dyes, displays of shorter duration at higher intensity are less damaging than displays of longer duration at lower light levels.

This research is contrary to the current understanding of how light damages materials and may be an indication of the limitations of data gathered from accelerated aging testing coupled with the complexity of understanding light radiation. Conservators disagreeing with Wilhelm and Hendrik's opinions cite conservation's ethical goals to protect materials for as long as possible through insightful balance of the known damaging effects of display. If the material will fade or be damaged by display, additional precautions, instead of abandoning of precautions, would be a more suitable action for preservation of these materials.

However, others have noted that the intent of Wilhelm and Hendriks's statements was misinterpreted. Displaying photographic material at the most minimal light levels when appreciation of the medium demands a higher light level is a disservice to the artist's intent and frustrating to the viewer. If higher light levels are used, consideration should be given to reducing the number of hours these materials are on display and using a lighting source with the least damaging light spectra output for that photographic process. Wilhelm (1993, 230) suggests color balance should be considered as much as potential fading and density changes in determining appropriate lighting levels.

Some institutions are collecting two copies, one intended for display, another for preservation. When the display copy is "exhausted," the question remains whether a duplicate will be made for continued display or, as some curators have suggested, the second preserved print will be available for display.

This issue of suitable light levels and suitable length of display of color photographic materials remains controversial, and the discussion continues.

1.4.1.3.3 Assessment by fading of monitoring standard

1.4.1.3.3.1 Blue Wool Standard

Blue Wool Standard BS1006 (1978) or International Organization for Standardization (ISO) standards for sensitivity to light was utilized at the Montreal Museum of Fine Arts (MMFA), Canada, to assess suitability of materials for exhibition and to clarify and quantify the institution's exhibition policy. An "important advantage is that [this system] can be used to communicate concepts of fading to non-specialists, and tends to be more convincing than vague warnings. Effective communication of the rationale behind protective policies is essential if cooperation or support in their implementation is to be forthcoming. Exposure recommendations are based on regular yearly use, with the recommendation that exhibitions never exceed twenty weeks, regardless of accumulated storage time. It is assumed that ultraviolet radiation (UV) has been filtered out or is excluded from the light source. The figures in the policy have been based on a 42 hour exposure week with an intensity of 10 fc (107.6 lx) for categories 2 and 3 works, and 7.5 fc (80.7 lx) for category 1 works." Individual works were assessed into three categories (Colby 1993, 4 to 5) See next page:

Category #1 Sensitivity levels ISO 1, 2, or 3 (sensitive)
- 1115 fc-hour/year (12,000 lx-hour/year)
- approximately four weeks exposure limit at 7.5 fc
- predicts a "just noticeable fade" in 100 years

Category #2 Sensitivity levels ISO 4, 5, or 6 (intermediate)
- 3,903 fc-hour/year (42,000 lx-hour/year)
- approximately ten weeks exposure limit at 10 fc
- predicts a "just noticeable fade" in 250 years

Category #3 Sensitivity levels ISO 7, 8 or above (durable)
- 7,807 fc-hours/year (84,000 lx-hours/year)
- approximately 20 weeks exposure limit at 10 fc
- predicts a "just noticeable fade" in 3500 years

The display lighting policy at the Victoria and Albert Museum, London, is based on the British Blue Wool Standards and perceptible change concept introduced by Stefan Michalski in 1997. Initially, the policy had two categories, sensitive (approximately ISO 4 and below) and durable (ISO 5 and above). The two categories primarily separated material by color versus black-and-white media and condition of support. An exception was the "zero tolerance" items such as photogenic drawings. Items in the sensitive category had a 20% display time at 50 lux. In 2001, the policy proposed four categories called vulnerable (formerly "zero tolerance"), sensitive, durable, and permanent. Materials in the vulnerable category include photogenic drawings and a maximum of 50 lux is recommended. Materials in the sensitive category include color photographs and lighting at ISO 4 and below is recommendation. Materials in the durable category include black-and-white fiber-based photographs and lighting at ISO 5 and above are recommended. Materials in the permanent category include stone and metal items that can be displayed at up to 27.9 fc (300 lx). (Ashley-Smith 2002).

An historic association exists for the use of the Blue Wool Standard in conservation. Many dyes used in late 20th – early 21st century printers (e.g. inkjet) have a basis in the textile industry where the Blue Wool Standard is still used. Commercial ink manufacturers incorporated the use of the Blue Wool Standard when adopting ink technology. However, blue wool patches have relative light fading rates, which vary depending on the light source as indicated by research conducted by Dr. Robert Feller at various institutions, by Henry Wilhelm, and at the Image Permanence Institute.

1.4.1.3.3.2 Light sensitive polymer dye

Many types of photographic materials will fade and can be otherwise damaged before the most sensitive sample of the Blue Wool Standard scales will fade. Therefore, Dr. Bertrand Lavédrine, director of the Centre de Recherches sur la Conservation des Documents Graphiques (CRCGD; Center for Research on the Conservation of Graphic Documents), developed a more sensitive gauge designed to be a cost-effective monitoring method. It is paper coated with a blue-dyed polymer that will shift in color from blue to violet to pink until fading to white at approximately 9293.68 fc (100 kilolux hours) (Lavédrine 1998).

1.4.1.3.3.3 LiDo (light dosimeter)

Based on Lavédrine's work, LiDo (light dosimeter) is intended to be similar "to the current blue wool standards ISO 105-B01, but more sensitive than the present Blue Wool Standard One. The product will give an early warning to the potential of light induced damage," (Römich, 2003) so may be useful in monitoring the light sensitivity of photographic prints. One prototype, LiDo (sensitivity one), has been successfully tested. Another prototype, LiDo (sensitivity four) is still in development. The target release for the dosimeter is 2004. LiDo development is a collaborative effort between

Fraunhofer-Institut fur Silicatforschung (FhG/ISC), Centre de Recherches sur la Conservation des Documents Graphiques (CRCGD), Insitutio di Ricerca sulle Onde Electromagnetiche "Nello Carrara", and the Victoria and Albert Museum.

1.4.1.3.3.4 Microfading Tester (Oriel® Fading Test System)

Paul Whitmore, with assistance from his colleagues Xan Pan and Catherine Bailie of the Carnegie Mellon Research Institute, Research Center on the Materials of the Artist and the Conservator, developed what they called a microfading tester, currently marketed as the "Oriel® fading test system" by Spectra-Physics. This instrument samples a small area (0.4 mm) with intense light. Reflectance spectra data are gathered, and a computer software program provides real time visuals (charts and graphs) as fading occurs. With information gathered in less than five minutes, the software can also extrapolate the data to predict long-term rates of fading. The test area and amount of fading are generally imperceptible to the unaided eye. As the light level is high, true reciprocity of some materials, such as chromogenic prints, cannot be accurately predicted with this method. The range of the microfading tester is 400-700 nm devoid of ultraviolet radiation that is the cause of much fading. The Carnegie Mellon research team is working on outfitting the machine with a light source that includes ultraviolet radiation (Whitmore et al. 1999). The largest factor limiting this machine and software at present is its cost of US$17,500.

Accurate prediction of fading from light exposure in exhibition would necessitate the use of fiber optics with similar light spectra as the microfading tester. It is desirable when lighting photographs to eliminate ultraviolet radiation. Therefore, the current range of the tester may be suitable for assessing fading risks for materials intended for display. The accuracy of the information specific to the unique photograph tested may well warrant the minute fading caused by this machine. Even if the machine can predict only an approximate range for some materials, the alternative has been for individuals to estimate a range based on previous observation of materials of like kind or produce time-consuming density and color monitoring data also minutely light damaging. The size of the photograph relevant to the 0.4 mm test area should also be considered.

1.4.1.3.5 Assessment by density changes using monitoring equipment

The conservation community has not yet agreed upon one monitoring standard for photographic materials. There can be confusion in trying to compare data from various monitoring machines and methods. In addition, monitoring is time consuming (see section 1.5.1).

1.4.2 Temperature and relative humidity

1.4.2.1 History of standard

Many institutions have established internal guidelines and parameters for suitable environmental conditions during exhibition. There are no commonly agreed upon standards for temperature and relative humidity levels, however, research is ongoing. Organizations such as American National Standards Institute (ANSI) and International Organization for Standardization (ISO) have been steadily issuing standards for contemporary photographic materials. It is currently believed that fluctuations in relative humidity, rather than temperature, can be more damaging to many photographic materials. Deterioration rates based on the Arrhenius equation are often quoted (chemical deterioration doubles with every increase of 18°F [10°C]) in the literature.

1.4.2.2 Current guidelines and recommendations

1.4.2.2.1 General standards

A temperature of 65°-75°F (18°-24°C) is recommended. "Daily cycling of more than 5-8°F (4-6°C) must be avoided" (Hendriks et al. 1991, 436). Some institutions have begun recommending even tighter restrictions of daily fluctuations under ± 3°F (2°C).

A consistent 40- 45% ± 3% relative humidity is recommended (Mathey et al. 1983). A consistent 30-50% relative humidity has also been recommended (Reilly 1986, 82).

The National Information Standards Organization (NISO), Committee MM, worked during the 1990s on a draft of standards for exhibition of library and archives materials (Z39.79-1999) that included photographic materials. The NISO standards draft cited a temperature of 72°F (22°C) with a maximum variance range of 5°F (3°C) without shifting more than 5 degrees in any 24-hour period. This temperature was in conjunction with a general range of 30-50%, relative humidity allowing a seasonal drift of 5% over one month and no more than a 5% shift in any 24-hour period.

Seasonal variances of highest and lowest acceptable range, or set points, can be set for environmental control systems to compensate somewhat for mechanical limitations of HVAC systems. Set points may also vary with region and location, such as coastal areas versus interior land locations, but they should aim as close to the guidelines as possible. It is advisable to maintain levels as consistently as possible. For the preservation of photographs, changes in humidity and temperature levels should be gradual.

Please refer to the standards organizations in section 1.8 for contact information to obtain current standards.

1.4.2.2.2 Institutional guidelines and recommended standards

Temperature and humidity guidelines and standards established for institutions are often based on established standards set for paper items. Many institutions do not set a separate standard for photographic materials. Information listed here was gathered by an informal survey beginning in 1995 and augmented by compilers. It is provided as reference. Please consult individual institutions as necessary for current guidelines and recommended standards.

Institution (In house publication date, 1995 otherwise)	Temp. °F	24 hour	Temp. °C	24 hour	Relative Humidity %	24 hour fluctuation
National Gallery of Canada	Max 64-72°	± 2°	Max 18-22°	± 2°	Winter 44%; summer 50%	± 3% daily fluctuation
Museum of Fine Arts, Boston, MA (2000)	70°		21°		50% maximum	
International Museum of Photography at the George Eastman House, NY	69-74°	± 3°	20.5-23°	± 3°	37-50%	± 5%
Philadelphia Museum of Art, PA	68-72°		20-22°		50%	± 5%
National Galley of Art, WDC (1998)	67-77°	± 5°	19-25°	± 5°	50%	± 5%
Library of Congress , WDC (1986)	70°		21°		45-55%	

Institution (In house publication date, 1995 otherwise)	Temp. °F	24 hour	Temp. °C	24 hour	Relative Humidity %	24 hour fluctuation
Art Institute of Chicago, IL (ca 1990s)	68-70° during exhibit		20-21°		40% ideal	± 5%
Art Institute of Chicago, IL (ca 1990s)	65-75° otherwise		18-24°		40% ideal, 35-55%	Without rapid change
Detroit Museum of Art, MI	68°	± 2°	20°	± 1°	45%	± 5%
Cincinnati Museum of Art, OH (1996)	70°		21°		50%	
Humanities Research Center at the University of Texas at Austin, TX (2004)	70°	± 2°	21°	± 1°	45%	± 5%
J. Paul Getty Museum of Art, CA	67°	± 3°	19°	± 2°	45%	± 5%
British Library [ca 1990s]	Max 68°		Max 20°		30-40%	
Victoria and Albert Museum, UK (1998)	68°		20°	18-25	50%	± 5%; max range 45-60%
National Historic Trust, UK (1988)	Below 60°		Below 15.5°		45-55%	
Bibliothèque Nationale, FR (1988)	60-68°		16-20°		50-60%	

1.4.2.3 Recommendation by material

For cased materials, relative humidity levels no higher than 50% and possibly as low as 40-45% will reduce the potential for glass deterioration or condensation within the package, but will be high enough not to desiccate the leather, wood, textile, and paper components of the case and daguerreotype, ambrotype, or tintype package. Ambrotypes and tintypes commonly have at least one layer of a natural resin varnish. Therefore, heat and humidity probably pose the greater risk than does the actual level of illumination. However, light levels should not exceed 10-15 fc (107.6-161.4 lx).

1.4.2.4 Regulating approaches to humidity and temperature

1.4.2.4.1 Heating, ventilation, and air conditioning (HVAC)

There are no standard heating, ventilation, and air conditioning (HVAC) systems applicable to all photographs in all exhibition or building situations. Specifications for HVAC systems are beyond the scope of this document. It is best to consult with a HVAC engineer to determine appropriate systems for each building, exhibition space, or exhibition case. Some general guidelines for operating HVAC systems follow:

1. Perform regular maintenance of the HVAC system for optimum system efficiency.
2. Perform regular filter changes to reduce likelihood of reemitting atmospheric contaminates and particulate matter if activated carbon / charcoal filters are used.
3. Use close-range set points (e.g., 68-72°F or 20-23°C) for maintaining consistent environmental conditions. Allow for seasonal drift if determined necessary.

1.4.2.4.2 Enclosed microclimate

An enclosed microclimate within a case can be maintained at a predetermined humidity range with preconditioned amorphous silica (e.g., Silica Gel, ART-SORB™, or ARTEN™) and housing materials that are naturally hygroscopic as appropriate to each situation (papers, boards, batting).

1.4.3 Air Quality

1.4.3.1 Types of pollutants

Photographic materials are sensitive to even trace amounts of airborne pollutants. Pollutants damaging to photographic materials include, but may not be limited to (alphabetically), acetic acid, ammonia, formaldehyde and formic acid, nitrogen oxides, ozone, peroxides, and sulfur compounds such as hydrogen sulfide and sulfur dioxide. Particulates damaging to photographic materials include, but may not be limited to (alphabetically), conidia (mold spores), dirt, sand and sea salt, soot, tar and nicotine smoke from cigarettes, cigars, and pipes.

1.4.3.2 Standards, guidelines, and recommendations

Pollutants are not considered safe at any level. The goal is to get levels down as low as possible with the available technology. Accuracy of instrumentation is critical to monitoring. It is unrealistic to set any limits that cannot be measured with available equipment. For example, all of the following recommendations by Thomson (1986) are within error ranges of most contemporary instruments.

1.4.3.2.1 Carbon dioxide

The recommended limit for carbon dioxide (CO_2) level is □4.5 $\mu g/m^3$ (micrograms per cubed meters) in archival storage areas (Mathey et al. 1983).

1.4.3.2.2 Ozone

The recommended limit for ozone (O_3) level is □2 $\mu g/m^3$ in general museum collections (Thomson 1986, 268). A level of □25 $\mu g/m^3$ is recommended for archival storage areas (Mathey et al. 1983). The Library of Congress, Washington, D.C. proposes levels of less than 0.94 parts per billion (ppb). However, general instrument background noise levels inside can be as high as approximately 10 ppb. If the inherent noise level of the machine can be brought down to 5 ppb, monitoring is possible.

1.4.3.2.3 Sulfur compounds

Sulfur dioxide (SO_2) is measurable at 2-5 ppb. Recommended limit for sulfur dioxide level is □1 $\mu g/m^3$ in archival storage areas (Mathey et al. 1983). Less than 10 $\mu g/m^3$ level is recommended for general museum collections (Thomson 1986, 268).

1.4.3.2.4 Nitrogen oxides

The recommended limit for levels of nitrogen oxides (NOx) is □5 $\mu g/m^3$ in archival storage areas (Mathey et al. 1983). A 10-$\mu g/m^3$ limit was recommended for general museum collections (Thomson 1986, 288). Ozone (O_3), sulfur dioxide (SO_2), and hydrogen sulfide (H_2S) are easily removed with activated carbon filter banks, but nitrogen oxide (NO_2) is not. Rather than place unrealistic limits on maximum levels of acceptable NO_2, it is better to set lower limits for the other gasses that are more easily removed.

1.4.3.3 Detection of pollutants

1.4.3.3.1 General and multiple types of pollutants

The Photographic Activity Test (PAT), ISO 14523:2000 (formerly ANSI IT9.2-1991 and ANSI.IT9.16-1993), is useful for determining the suitability of fibrous and plastic materials for use in cases. The PAT tests materials by manufacturing batch, not recipe or type. Colloidal silver film is placed in between the materials to be tested. The package is placed in an oven, and heat and humidity are cycled for 14 days. Upon removal, if the colloidal silver film is spotted significantly, if the gelatin is discolored yellow, or if a change of density has occurred, the material fails the test.

Research by Edith Weyde and associates (1972) indicates that colloidal silver test strips can be placed in collections to monitor harmful air pollutants. A strip of colloidal silver (grain size less than 30 nm) is placed in the area to be tested. The test is time dependent. The faster the strips darken, the more pollutants that are in that environment. Darkening occurring in a few weeks is considered to indicate higher risk; darkening occurring over a few years is considered to indicate lower risk. The identity and source of the possible pollutants are not established with this testing method. Additionally, this test is very sensitive, and oxygen and moisture in air have been corrosive enough to attack the silver strips.

The Oddy test tests for the presence of volatile, corrosive gases by monitoring metal corrosion. The test is relevant to photographic materials because many final image layers are combinations of metallic particles. The sample material to be tested and cleaned, abraded, and scratched coupons of copper, lead, and silver are artificially aged together at 140°F (60°C), 100% humidity for a minimum of a week (28 days preferred). The amount of corrosion developed is compared to control strips. Subjective interpretation of corrosion amounts determines how the material is classified (Green and Thickett 1994, 8; Richard et al. 1991, Section 8). Problems with the Oddy test are that it takes considerable time to get the results, and the assessments are subjective. Strict controls must be maintained during testing to achieve comparable test results. Recently, there has been controversy regarding whether the test is sensitive enough to detect corrosive gases at the levels at which photographic materials are at risk for damage. Revision of the test may control or limit inherent variables and resolve some of these concerns. To improve on the Oddy, an electromechanical method for testing corrosive volatile materials has been researched by the University of Delaware Art Conservation Department in collaboration with the National Park Service Division of Conservation, Harpers Ferry Center (Reedy et al. 1998).

Dräger rapid detection tubes "can detect the presence of several types of gases, such as organic acids, hydrochloric acid, and formaldehyde. The detection tubes have a lifetime of around two years" (Tétreault 1992, 3).

Solid Phase Microextraction (SPME) techniques used in conjunction with gas chromatographs (GC) can detect very small sample sizes of various pollutants. Janusz Pawliszyn at the University of Waterloo in Ontario, Canada invented SPME in the early 1990s. "The SPME fiber is coated with a liquid (polymer), a solid (sorbent), or a combination of both. The fiber coating removes compounds by absorption in the case of liquid coatings or adsorbtion in the case of solid coatings. The SPME fiber is then inserted directly into a gas chromatograph for desorption and analysis" (Sigma-Aldrich 2004). SPME is solvent-free, reusable, and fast to use when a gas chromatograph is available.

1.4.3.3.2 Organic acids such as acetic and formic acids

The iodide/iodate test identifies the emission of organic acids such as acetic and formic acid. A solution of iodide/iodate is encased along with the test material at a temperature of 140°F (60°C) for 30 minutes. A blue color in the solution confirms the presence of volatile acids (Green and Thickett 1994, 10; Zhang et al. 1994).

PH indicator paper can be adapted to test for acidic volatile gases using inexpensive materials usually found in a conservation lab. The acidity of the emissions from a material is measured. Glycerin (or glycerol) is applied to a pH indicator paper (pH 4-7 range is most practical). The glycerin-impregnated pH paper must be stored in a well-sealed container until use. Within an airtight container, suspend the material to be tested and the indicator paper or place both on an inert clean surface during testing lasting for 24 hours. Compare the results against the control pH indicator. The color of the pH indicator changes with the amount of acid absorbed by the solution" at a particular temperature (Tétreault 1992).

Acid-Detector (A-D) strips (bromocresol green) are a nondestructive test that determines the presence of acetic acid (pH range 3.8–5.4). The sample and strip are placed in a relatively sealed environment (such as a Ziploc™ plastic bag). After 24 hours, the extent of color change indicates the level of acetic acid present (Image Permanence Institute test kit 1995). While specifically designed to detect acetic acid off-gassing of photographic film, A-D strips have been used to test for the presence of "other acids released by adhesives, papers, textiles, wood products, and plastics for screening conservation and exhibition materials" (Nicholson and O'Loughlin 1996b).

1.4.3.3.3 Chlorine, bromine, or iodine inorganic compounds

The Beilstein test will detect the presence of chlorine, bromine, or iodine in organic compounds. Clean copper is heated and touched to the sample material to be tested, and the sample is burned in a flame. If the flame turns blue-green, chlorine, bromine, or iodine is present in the sample and the material is unsuitable for use with photographic materials. Certain compounds such as quinoline, urea, and pyridine derivatives give misleading blue-green flames owing to the formation of volatile copper cyanide with this test method, but these materials are generally not considered safe for photographic materials either (Green and Thickett 1994, 9).

1.4.3.3.4 Formaldehyde

The chromotropic acid test confirms the emission of formaldehyde. This test can be used to determine the suitability of housing and construction materials for use on exhibit, not on original photographic materials intended for display. Personal protection equipment and caution are required when performing this test. Chromotropic acid (4,5-dihydroxynaphthalene-2, 7-disulphonic acid) in concentrated sulfuric acid is enclosed with the sample to be tested and heated at a temperature of 140°F (60°C) for 30 minutes. Yellow solutions indicate no formaldehyde; violet blue indicates formaldehyde (Zhang, et al. 1994). Other tests exist but require more sophisticated apparatus. For those with access to an analytical laboratory, see the test methods used by Hatchfield and Carpenter (1987) and Hatchfield (1999).

1.4.3.3.5 Sulfides

The azide test detects the presence of reducible sulfide in fibrous materials. This test can be used to test the sulfur content of display materials. Personal protection equipment and extreme caution are required when performing this test. A solution of sodium azide, iodine, and ethanol are applied to fibers on a glass slide under a microscope and observed for about two minutes. Sulfur azide and iodine form nitrogen gas when in contact with sulfur. Particulates on the sample can interfere with the test (Daniels and Ward 1982).

Sulfide "traps" (3M's Oxidation Arrest Paper) have been used to detect and remove airborne sulfides from enclosed daguerreotypes (Mustardo 1986).

1.4.3.3.6 Cellulose Nitrate

The diphenylamine spot test detects the presence of cellulose nitrate and can be performed on materials used in housing of photographic materials or construction of exhibition spaces. The spot test is done with a solution of 0.05% diphenylamine in 90% sulfuric acid and water. Personal protection equipment and caution are required when performing this test. The solution should be made in a fume hood. It is highly corrosive and should be stored in glass bottles with plastic caps resistant to sulfuric acid. A tiny sample is placed on a glass or white porcelain surface. A single drop of reagent is placed on the sample while ensuring that the dropper does not touch it. A blue-violet stain indicates the positive presence of cellulose nitrate. All other scenarios (no color change, orange, yellow, brown, or green) indicate a negative result. This test is very sensitive so care must be taken when gathering a sample. Even trace amounts of residual adhesive, for example, will test positive (Williams 1988).

Cresol red (o-cresolsulphonephthalein) or Cresol purple solutions applied to filter paper have been used to detect the presence of nitrogen dioxide from decomposing cellulose nitrate (Fenn 1995b, Hatchfield 2004). See also Zhang et al. (1994) and Hatchfield (2002).

1.4.3.4 Reduction of airborne pollutants

1.4.3.4.1 General corrosive gasses

In general, many techniques for reducing and removing airborne pollutants make use of adsorbents and scavengers.

Activated carbon/charcoal has been found to remove the widest range of pollutants (Grosjean and Parmar 1991). Carbon is a true "buffer" in that it will absorb pollutants until full, then will re-emit what has been stored. Activated carbon/charcoal filters should be changed at pre-established intervals before the material is exhausted of the capacity to absorb. As there is no indicator to detect saturation of charcoal/carbon, a small number of potassium permanganate pellets can be added. When the potassium permanganate turns from purple to gray, it is time to change the filter. As potassium permanganate and charcoal do not adsorb the same chemicals at the same rate, mixing the two to achieve a visual indicator should be taken as a general, not a specific indicator.

Activated carbon is an example of a natural zeolite molecular trap. Synthetic zeolites can be designed to trap specific molecules by forming chemical bonds with volatile materials. Conservation Resources Incorporated's Microchamber® product line of paper and board materials are a combination of alpha-cellulose pulp, synthetic zeolites (such as crystalline alumino-silicates), and alkaline reserve of calcium carbonate. Some products are manufactured with activated carbon layers. The manufacturers claim the materials will remove acetic acid, formic acid, phenols, aldehydes, hydrogen peroxide, ozone, sulfur dioxide, hydrogen sulfide, carbon disulfide, nitrogen oxides, ammonia, and formaldehyde (Rempel 1996, product literature 1995). Conservation Resources Incorporated has leased the technology to Nielsen & Bainbridge, which manufactures Alphamat® ArtCare™ product line of mat boards. The boards consist of alpha-cellulose pulp, synthetic zeolites, and alkaline reserves (Nielsen & Bainbridge product literature 1996). While these materials seem wonderfully promising and potentially better than currently available paperboard with alkaline reserves, time and natural aging have not yet confirmed whether they will live up to the extent of the manufacturer's claims.

"Activated Carbon Cloth" contains 100% activated carbon that is advertised "to absorb contaminants such as acetic acid, but will also remove odors from deteriorating organic objects and reduce water vapor, thereby reducing humidity" (University Products advertising literature 1999).

Mead Company also produces a carbon paper that is 50% carbon by weight. Other products such as activated charcoal cloth and 3M's silver protector strips have been used to remove nonvolatile chlorides from within metal decorative arts cases (Hatchfield 1996).

Potassium permanganate ($KMnO_4$) (4%) impregnated in activated alumina, Purafil™, is effective in reducing gaseous pollutants in frames and cases (Grosjean and Parmar 1991). A change of color from purple to black indicates that absorption capacity has been reached, and the materials will not re-emit pollutants unlike carbon. Purafil™ is available in a variety of forms, such as pellets, granules, papers, and boards (Hatchfield 1996).

"Corrosion Intercept" film (molecular copper) can be an optimum barrier film (double foil outer layer with molecular copper interior). It tested better than Marvel Seal 360™ in initial tests at the Museum of Fine Arts, Boston, in 1996 (Hatchfield 1996). The material turns black when the copper is exhausted. It may also have some antifungal capacity, although this is not yet quantitatively proved. It has been used in enclosure designs for daguerreotypes.

"Tarnish Inhibitor Capsules and Plastabs" are advertised as "corrosion inhibitors for ferrous, non-ferrous metals, and glass-plate negatives. Proprietary formula. Effective life is approximately one year" (Conservation Resources catalog 1995).

1.4.3.4.2 Acetic acid

Kodak's molecular sieve "Acid Scavenger" desiccant is advertised for use with triacetate, polyester, and nitrate film bases with black-and-white or color emulsions. "The material is stored in a semi-permeable packet of Tyvek™ which allows vapors to be easily scavenged and contained" (Kodak product literature, n. d., ca. mid-1990s). The manufacturer claims the product reduces the moisture in an enclosed case, thus potentially slowing down chemical processes such as the formation of acetic acid (vinegar syndrome) and reducing the possibility of fungal growth. The manufacturer also claims the product reduces oxidation reactions from peroxides and ozone.

1.4.3.4.3 Sulfides

Zinc oxide pellets (ICI's Puraspec 4020) have helped lower hydrogen sulfide concentrations (and thereby reduced tarnishing on silver artifacts) when placed in an exhibition case in the British Museum (Green and Thickett 1994). A solid granule adsorbent (Miracle Sac™) has been used to lower concentrations of sulfides that cause tarnishing of metal artifacts in storage.

Thomson (1986, 158) reports that copper-impregnated activated carbon (Sonoxcarb™) filters are effective in reducing levels of pollutants particularly sulfur dioxide.

3M's Oxidation Arrest Paper, developed by Robert Wieman in the mid-1970s, , with an active ingredient of activated charcoal impregnated into paper, can remove ambient sulfides within cases. 3M's silver protector strips have been used in metal decorative arts cases at the Museum of Fine Arts, Boston, since the 1980s.

1.4.3.4.4 Nitrates

According to Hatchfield (1996), vapor phase inhibitors are not effective in removing amino nitrates, which are very difficult to remove.

1.4.3.4.5 Formaldehydes

It is known that ferns, such as spider plants, help break down gases such as formaldehyde, but using plants in exhibition spaces should be carefully considered. Plants can produce higher humidity levels and attract insects, although potential insect infestations can be mitigated through a consistent integrated pest management program.

1.5 EQUIPMENT AND MATERIALS: CONSIDERATIONS

1.5.1 Monitoring equipment

1.5.1.1 Visual observation

Visual inspection of photographs may detect changes and damage but it is unreliable. Perceptions of color cannot be easily remembered and with increasing age, one's ability to see contrast and to distinguish between subtleties in color change diminishes. Also, perception of color varies with lighting conditions (color temperature and lumen level): the lower the light levels, the greater the change must be before it can be perceived. Changes to a photograph may be very slow to become visibly noticeable. Frequent checking of materials for changes might catch drastic fading or color shifts, but checking is time consuming. Relying on visual observation to detect changes is to wait until the change is significant.

1.5.1.2 Instrumental monitoring

The conservation community has not yet agreed upon one monitoring standard for photographic materials. It is confusing to compare data from various monitoring machines and methods. With all methods, it is necessary to make a template for each photograph in order to orient the machines to the same site, before, during, and after exhibition.

1.5.1.2.1 Reflection densitometer

The reflection densitometer measures the amount of light reflected from the surface of an image and gives a numerical set related to the densitometry standard used in the photographic industry. Consult the most current ANSI/ISO standards, including:

ANSI/ISO 5-2: 1991, ANSI/NAPM IT2.19-1994 (Photography -- Density Measurements -- Part 2: Geometric Conditions for Transmission Density);
ANSI/ISO 5-3: 1995, ANSI/NAPM IT2.18-1995 (Photography -- Density Measurements -- Part 3: Spectral Conditions);
ANSI/ISO 5-4: 1995, ANSI/NAPM IT2.17-1995 (Photography -- Density Measurements -- Part 4; Geometric Conditions for Reflection Density).
ANSI/NAPM IT9.9-1996 (Imaging Materials-Stability of Color Photographic Images - Methods for Measuring). Corresponding ISO document is ISO 10977:1993.

The advantages of densitometers include ease of use, simple and reliable calibration, and that computer programs are not required for interpretation. Densitometers are the least expensive of current choices and are the standardized equipment found most commonly in museums and other institutions. Current stability standards are written in terms of density change and a body of readings has been developed. The machines are good at comparing between samples at any one time and for monitoring changes in an image area, although less so in white areas. Densitometers provide quantitative proof of change that custodians can follow much more easily than other types of instrumental monitoring equipment. Densitometers are easy to transport, an important consideration when monitoring is a requirement for traveling exhibitions.

The disadvantages of densitometers include data limitations. They measure only the ratio of reflected light to incident light (a single quantity) over a broad spectral range. Densitometers do not relate changes to our perception as do colorimeters. Densitometers cannot detect changes in chromaticity and assume dye loss to be directly proportional to density loss. Regular maintenance (refurbishment and recalibration) and replacement of light source and filters is necessary to ensure quality of data. The reference tiles and filters need to be replaced every few years because they are not stable (Wilhelm 1993, 247). Densitometers have poor inter-instrument agreement; two densitometers may give different readings for the same sample.

1.5.1.2.2 Colorimeter

Colorimeters measure reflected light using red, green, and blue electronic photoreceptors (filtered sensors) and convert these tristimulus values to the chromaticity components of color (e.g., CIE, L* a* b*).

The advantages of colorimeters begin with ease of use. One reading incorporates hue, lightness, and chromaticity. Samples can be compared and the machines are good at detecting color shifts of "white" areas. The data format makes it easy for custodians to perceive visible change and provides quantitative proof of change that custodians can follow. Recently, more software has become available and some newer machines come with internal programs, making them simpler to use. More recently designed machines are easy to transport, an important consideration for monitoring traveling exhibitions. Colorimeters are widely used in the color industry and already used by paper and paintings conservators making them potentially available in nearby labs.

The disadvantages of colorimeters begin with the complexity of the machine that can be intimidating or confusing to learn to use. The interpretation of data is more complex than with densitometers and spectrophotometers, especially for black-and-white prints. Calibration in older machines may be difficult whereas newer models are straight-forward and no more difficult or unreliable than are densitometers. Regular maintenance (refurbishing and recalibration against a standard) and replacement of the light source are necessary to ensure quality of data. Reference tiles must be replaced every few years. "Reference readings" need to be established before and after any maintenance or repair to detect any large reading shifts. Colorimeters have poor inter-instrument agreement; two colorimeters may give different readings for the same sample. The lack of standard observer angle, geometry, or illuminant can lead to varying results among operators or readings. The cost for a colorimeter is less than a reflection densitometer and more than a spectrophotometer.

1.5.1.2.3 Spectrophotometer

The spectrophotometer measures the ratio of reflected to incident light for one wavelength at a time, scanning through the desired wavelength range. The resulting "spectrum" represents the reflectivity of the measured sample at each wavelength.

The advantages of spectrophotometers include reliability, maximum sensitivity, versatility and control. Calibration is not necessary with modern, so-called "double-beam" instruments and data collected can be output in colorimetry units. The machines provide reflectance curves and numerical data as color coordinates. Newer models are easier to travel with than older models, an important consideration for monitoring traveling exhibitions. Spectrophotometers are the best choice for long-term monitoring of in-house collections and exhibits because readings are less prone to differences from differing operator technique or multiple operators.

The disadvantages of spectrophotometers include cost, as these are the most expensive machines of all the current choices. Calibration plates are easily breakable and expensive to replace. However, machines using aluminum oxide plates can be cheaper as rubbing the plates together can clean them. The top surface is removed a little, but can last a long time. Older machines are difficult to transport to multiple sites necessary for monitoring a traveling exhibition. Considerable time is needed to take measurements and generate the data. Taking reliable measurements requires some training and understanding of the science involved. The data provided by the machine is complex and copious. Nonscientific custodians will need interpretation of the data. Finally, few institutions or private conservators can afford to purchase or maintain spectrophotometry equipment.

1.5.1.2.4 Statistical analysis of data from monitoring

Error can be random, affecting the precision of the result, or systematic, affecting the accuracy of the result. Operator error, misalignment of the machine, poor instrument precision, and instrument drift contribute to statistical errors. Reduction of errors can be achieved with consistency in measuring, repeated readings of a single site, and realignment of the sample and measuring again. Standard deviation equations can be used to predict random error size. Some statistical calculations (linear regression) can be done on standard computer spreadsheet software. Confidence limits and t-tests are also available in computer statistics packages.

1.5.1.3 Visible and ultraviolet light meters

Visible and ultraviolet light meters are used to measure ambient and direct lighting levels. Light meters can measure footcandles (fc), lux (lx), microwatts per lumens (μW/lm), and color temperature (K, degrees Kelvin). Dial and digital liquid crystal displays (LCD) are available. Camera meters can be used as an estimated general measure of lux in an area (CCI 1983).

1.5.2 Lighting equipment

The wavelength of infrared, visible, and ultraviolet radiation is measured in nanometers, nm or 10^{-9} m.

1.5.2.1 Natural lighting

Photographs must never be exposed to direct sunlight because of its high illuminance (12,000 fc or 129,120 lx) and its rich ultraviolet content (Hendriks et al. 1991, 437). Indirect daylight must be filtered to remove the ultraviolet content and control brightness.

1.5.2.2 Artificial lighting

"Ultraviolet radiation content of lighting depends on the power and filament temperature of the lamp" (Knight 2001).

1.5.2.2.1 Incandescent tungsten lights

The color temperature of incandescent tungsten lights is typically within 2,700-3,100 K and will have an ultraviolet range of 65-75 μW/lm dependent on operating temperature of filament (Saunders 1989). Incandescent tungsten bulbs produce light strong in red-yellow appearance, but colored bulbs can be used to offset or balance this effect (Moor and Moor 1992, 196). The energy efficiency is less than other lighting sources for the brightness of the bulb.

Reilly (1986, 105) and Wilhelm (1993, 605) recommend tungsten incandescent lamps for the display of 19th century photographic prints. Some believe that tungsten lights give the best possible color rendition of monochrome photographic images. Reducing light intensity by using dimmers changes the color temperature of incandescent bulbs. Berrie has noticed that lowering wattage to reduce lux also increases infrared output (Phibbs 1997). Instead, the use of neutral density filters and metal screen mesh are recommended. Tungsten light bulbs generate heat through the burning of the filament, so fixtures and screens can get quite hot. Incandescent tungsten lights should not be set closer than 3 feet (1 m) during exhibition (Raphael 1991, 13).

Moor and Moor (1992, 196) have written that while "tungsten lamps have the lowest ultraviolet output rating," they believe the lights "still should be filtered for ultraviolet and infrared." However, the amount of ultraviolet light from a tungsten lamp is extremely low. Fitting ultraviolet filters to these light sources may not be worth the money. Wilhelm (1993, 605) warns that "Ilford Ilfochrome (Cibachrome) print materials, Fuji FI-10, and 800 Instant Color films, the obsolete Agfachrome-Speed reversal print material (marketed 1983-1985), and the initial versions of Kodak PR10 Instant Prints™ introduced in 1976, have cyan dyes that fade more rapidly under tungsten illumination.

1.5.2.2.2 Quartz halogen lamps (tungsten filaments, quartz-iodine bulb)

The color temperature of quartz halogen lamps typically stays constant at 3100 K with an ultraviolet region around 120 μW/lm. Bulbs and sockets cost more than most other forms of lighting but last two times longer, use less electricity, and generate less heat and infrared radiation than do traditional tungsten bulbs (Wilhelm 1993, 605).

Quartz halogen lamps have significantly higher ultraviolet output than other incandescent lighting sources and should always be fitted with ultraviolet filters. "Even a glass-filtered quartz halogen lamp emits almost twice as much ultraviolet radiation within the 350-400 nm region as an unfiltered incandescent tungsten lamp. The greater ultraviolet output of glass-filtered quartz halogen lamps is probably of little consequence in terms of the fading rates of Ektacolor™, Fujicolor, Konica Color, Agfacolor, and most other current color print materials." (Wilhelm 1993, 605) Heat-resistant glass (also known as heat-absorbing glass) should be fitted to these lamps. Quartz halogen lamps should not be set closer than 3 feet (1 m) during exhibit (Raphael 1991, 13).

1.5.2.2.3 Fluorescent lights (phosphor re-emission)

The color temperature typical of fluorescent lights is 3000-5000 K with an ultraviolet region within 40-150 μW/lm, although the amount of ultraviolet content varies with lamp type and style (Saunders 1989), power and filament temperature of the lamp (Knight 2001). Fluorescent lights have four times greater efficiency than tungsten sources with one-quarter the emission of heat and infrared radiation (Wilhelm 1993, 606). The average lifetime for tube-style fluorescent lights is 9000 hours.

Fluorescent illumination alone gives extremely poor color rendition of monochrome and color images due to non-continuous spectral output. Fluorescent lights should be filtered due to the ultraviolet output that is usually emitted at 313 and 365 nm and peaks at 405, 408, 436, 546, and 578 nm (Wilhelm 1993, 606). Moor and Moor (1992, 196), based on recommendations from Thomson, Hendriks, et al. state that fluorescent lights should be filtered "to below 75 μW/lm with filters and baffles." Fluorescent lights should not be set closer than 2 feet (610 cm) during exhibit (Raphael 1991, 13).

1.5.2.2.4 Fiber optic and light piping systems (can also be installed as a lighting fixture)

The color temperature for fiber optic and light piping systems will depend on the source lighting. Color temperature does not vary with reduction of the light level. Light piping and fiber optic systems transmit neither ultraviolet nor infrared components. High ultraviolet-emitting light sources can decrease the longevity of plastic piping. Filters over the light source may be desired in this circumstance (Sease 1993). Fiber optic and light piping are more cost efficient than other lighting types as one source will illuminate several areas. The longevity of lamps depends upon type.

Sease (1993) notes that fiber optic and light piping systems are flexible and cost effective for design cases. The lighting source can be set up exterior to cases. Optical lighting film can be rolled into tubes, curved, and cut to size although there is a slight intensity loss with length and number of bends. Optical lighting film does not need to be "refocused" if the lighting source needs replacement and can be used as a spotlight or as general illumination. The estimated life of film made of transparent acrylic or poly (carbonate) polymer is 10 years. The film is smooth on one side and grooved on the other, thereby acting as total internal reflection mirror (Sease 1993). Glass piping has a more focused light and is likely to be longer lasting than plastic.

Directional lighting is useful when exhibiting many types of photographic media that are light sensitive. A daguerreotype plate is easier to see when directional lighting is used in the same direction as the parallel polishing marks inherent in the process (see Reynaud 1989). Viewer-operated fiber optic mats (also known as "light on demand") can be used to illuminate wax paper negatives and transparencies from the reverse. (see also 1.6.3 Lighting Techniques and Bowers 1999).

1.5.2.2.5 Light emitting diodes (LED)

Light emitting diodes (LED) are being investigated for use with non-photographic materials (Kershner 2003), but are not recommended at present for use with photographic material. LED's may prove to have low tungsten-style wattage and have an advantage of long-life. However, use in exhibit is in the experimental stage.

1.5.3 Glazing and filter materials

1.5.3.1 Considerations of glazing choices including ultraviolet inhibitors and filters

Light, even the visible range, is damaging to materials. Filtering the light source for ultraviolet radiation is desirable but does not eliminate the threat of light damage to a photograph.

Wilhelm (1993, 612) suggests that "ultraviolet radiation can easily be reduced by using acrylic sheeting with an ultraviolet filter such as Lucite® SAR UF-3 or Plexiglas® UF-3" on individual framed photographs. Likewise, cases can be made with ultraviolet-inhibiting glazing or an ultraviolet-inhibiting film can be applied to the exterior. Ultraviolet-inhibiting film can be applied directly onto window interiors or exteriors of frame glazing. Film can also reduce heat and glare and protect glazing from breakage and impact, some to the extent of a bomb blast. Lull (1999) believes that ultraviolet absorbing acrylic panels and laminated glass with a poly (vinyl butyral) ultraviolet-absorbing film are better options for reducing ultraviolet radiation than using films on windows. Window films are very thin; they break down faster than the glazing because of sun intensity, and within a few years they can start to separate from the glazing. Ultraviolet-inhibiting filters often come with a 10-year guarantee but seldom last past five years. Films should be considered as short-term applications because of the potential for separation. Predicting how long a filter will last is difficult because viability depends on the light level, length of exposure, and newness of the material. Long-term filtering effectiveness can be monitored by checking periodically with an ultraviolet light meter.

Ultraviolet films are available as covers for fluorescent bulbs and should be long enough to cover the ends, where much ultraviolet radiation is emitted (Glaser 1994, 2). Some light fixtures reduce ultraviolet radiation because of the materials used in manufacture of the bulb.

Wilhelm (1993, 577, 607) has found that Ilford Ilfochromes/Cibachromes do not have an effective ultraviolet-absorbing emulsion overcoat so prints need to be protected from rapid fading by the use of ultraviolet-absorbing glazing such as, Plexiglas®UF-3. In addition, Kodak Dye Transfer® paper prints (dye imbibition process) do not have a UV-absorbing overcoat and can fade rapidly under high UV-conditions. Wilhelm (1993, 577) states that image fading of Ektacolor™, Fujicolor, Konica Color, Agfacolor, and most other current color print materials is caused primarily by visible light, not by ultraviolet radiation. Ultraviolet filters do little to increase the life of these color materials, largely because they are manufactured with an effective ultraviolet-absorbing emulsion overcoat.

Many modern photographs contain optical brighteners that fluoresce when excited by radiation within the 397-400 nm range. This includes, but is not exclusive to, energy emitted by tungsten light sources. The brighteners are fugitive and will fade and discolor.

1.5.3.2 Recommendations for glazing and filtering materials

Numerous glazing materials suitable for framing photographs are available from common picture glass to polymeric materials. Common picture framing glass reduces some ultraviolet wavelengths, but has a distinctive green cast. Low-iron glass, also known as "water white" glass, can be used instead, especially when color accuracy is required. The ultraviolet absorption is similar to regular picture glass. Laminates of glass and ultraviolet absorbing film materials, such as poly (vinyl butyral), silicon or urethane-based coatings, can absorb 97-99% of ultraviolet radiation below 380 nm. Anti-reflection coatings, such as silicon dioxide (SiO_2) and titanium dioxide (TiO_2), reflect less than 1% of surface light. Non-reflective coatings and non-glare glass, made with an acid-etch on one side, do not absorb ultraviolet radiation, but can reflect or disperse light. Non-glare glass is not recommended for display of original material as the glass must be in direct contact with the photograph to appear sharp.

Plastic glazing suitable for photographs made from acrylic, cast and extruded including poly (methyl methacrylate), and poly (carbonate) have the advantage over glass glazing of lighter weight and resistance to breakage upon impact. Weight considerations are important when displaying large framed or oversized photographs or designing traveling exhibitions and plastic sheets are generally less prone to breakage during shipping or handling. Acrylic glazing is available with ultraviolet inhibitors, abrasion resistance, and anti-reflection coatings. Poly (carbonate) sheets have been used in exhibitions of large, oversized photographs, although poly (carbonate) sheeting generally scratches easier and yellows faster than acrylic sheeting. Some poly (carbonate) brands offer an abrasion-resistant surface.

Wilhelm (1993, 577) recommends the use of glass (or clear Plexiglas® G if travel is indicated) rather than ultraviolet-inhibiting plastics to avoid color shift. Acrylite® OP3 and Plexiglas® UF5 have less of a yellow color shift than other plastic sheets used for glazing. "Water-white" or low-iron glass eliminates the problem of color shifts apparent in other glazing structures and has similar ultraviolet filtering effectiveness as other picture framing glass. However, it is weaker, so thicker sheets or laminates should be used (Phibbs 1997) which would also increase weight. Instead of using plastics, Wilhelm (1993, 607-608) prefers to filter the illumination source to reduce or eliminate ultraviolet light. The Polaroid Corporation (1983, 33) recommends for Polaroid® photographs acrylic glazing such as Acrylite® GP, Lucite® UF-4, Acrylite® OP-2, Lucite® UF-3, Plexiglas® UF, or glass.

Dichroic (two-color) or interference filters are made of heat resistant borosilicate glass and can be used in conjunction with light fixtures to absorb 99% of ultraviolet radiation below 400 nm. The color of the filter varies with transmitted or reflected light, and while light intensity is diminished, the dichroic filter does not fade.

1.5.3.3 Care and maintenance of glazing and filter materials

Wilhelm (1993, 523) recommends water-based nonionic detergents and warm water for cleaning glass. Many commercial brands of glass cleaner contain ammonia, which can damage dyes in color photographs. Schott AG product literature (2000) recommends the use of a damp chamois cloth to reduce static and dust. Thorough rinsing of cleaning agents, detergents, and soaps is recommended.

Mild soap and water cleaning may be best for plastics, also. In the past, companies producing plastics have recommended, alcohols (ethanol, methanol, and isopropanol) and mild acetic acid (vinegar) for cleaning their products, but these materials can cause crazing and cracking of rigid plastic sheets. Some companies now recommend naphtha and similar non-aromatic hydrocarbon formulations for cleaning plastic, but although these solvents are relatively safe for poly (methyl methacrylate), it is risky to use them on poly (styrene) or poly (carbonate). Personal protection equipment and suitable ventilation are needed for the worker to safely use these chemicals. Image Permanence Institute's acid-detection strips can be useful in determining if plastics (sheeting or exhibit cases) have been previously cleaned with acetic acid.

1.5.3.4 Commercial products for glazing and filtering

**WARNING/CONSUMER BEWARE:

* The composition of proprietary materials is subject to change without notification.
* With the passage of time, the information provided here will become outdated.
* Product information is provided as a guide only and is not an exclusive list.
* Each application is unique. Evaluate materials for suitability before use.

<u>Glass and glass laminates:</u>
CHB Industries: Hardglass™
Denglas: UV laminated Safety Glass, Anti-reflective, Quartzkote, Water-white
Sandel: Crystalview, Satinview, Preservation Clear, Superior Clear,
Schott Glas: Amiran® series, TN (thin)
Tru Vue: Conservation Series™, Clear, Museum, UltraClear AR, Reflection-Free,
Vision: Laminated Glass
Zuel: Photo Clear™ UV 100, Image Perfect®,

<u>Acrylic sheets:</u>
AtoHaas: Plexiglas® series: G, MC, UF-3, UF-4, UF-5
CYRO: Acrylite® series: GP (general purpose), AR (abrasion resistant)
Dupont/ICI: Perspex® series: VE
Dupont: Lucite® series: UF-3, UF-4; UF-5, SAR (super abrasion resistant)
SD Plastics: Polycast
Tru Vue: Optium™ Museum Acrylic, Reflection-free Acrylic

<u>Poly (carbonate) sheets:</u>
CYRO: Cyrolon® AR1, AR2
GE Plastics: Lexan®, Margard MR5000®

<u>Filters for window interiors and glazing exteriors:</u>
Madico L.T.D.: Saft-ee Shield F CLS-200-X, CL-400-X
3M: Glass Safe®, Scotchtint®, and Scotchshield®

<u>Dichroic (two-color) or interference filters:</u>
Bausch and Lomb: Optivex™ ultraviolet glass

1.5.4 Matting, backboards, and support materials

As of publication, conservators are divided on whether alkaline or neutral support materials should be used with photographic materials.

1.5.4.1 Considerations

ISO 18902 (2001) recommends that enclosures and supports used with photographic materials, whether black-and-white or color materials, have an alkaline reserve. This standard replaces ANSI IT9.2-1991, which stated only that support materials should be free of acids and peroxides. Materials with an alkaline reserve are generally considered safe for contemporary silver gelatin, resin coated prints as long as the materials do not remain in contact with the gelatin surface (Burgess and Leckie 1991 100). Initially, it was felt that alkaline boards would be detrimental to albumen prints (Reilly 1986), but more recent research at the Image Permanence Institute seems to indicate "that calcium carbonate buffering [on paper products and boards] is not by itself a major threat to albumen prints" (Reilly, quoted in Ware, 1994, 58). Acidic housing materials can cause changes in color dye materials and weakness in support materials.

Moor and Moor (1992, 197) believe that inert and compatible support materials must be used because photographic emulsions are sensitive to strong alkaline and acidic materials. Some conservators recommend that housing materials with 100% rag content without alkaline reserves should be used, especially in conjunction with photographic processes that are stabilized at an acidic pH or are composed of materials known to be chemically affected by strong alkali conditions. Examples include chromogenic and dye imbibition (e.g. Dye Transfer®) prints, cyanotypes, Vandyke brown, platinum, and palladium prints. Materials with alkaline reserve should not be used with daguerreotypes or cyanotypes. The alkaline salts in paper products have been shown to cause tarnish films, corrosion, and etching of the daguerrean surface (Barger and White 1991, 173, 203). Ware (1999, 131) notes, "It is now generally advised that cyanotypes should not be mounted on, or stored in buffered materials [paper boards made with calcium carbonate] in case they suffer alkaline deterioration." Research has proved that alkaline solutions can destroy Prussian blue, ferric ferrocyanide, the image material for cyanotypes. Another conclusion is that salted paper, photogenic, Vandyke brown, platinum, and palladium prints do not have a protein binder (susceptible to attack by strong alkali; specifically, calcium carbonate is potentially hazardous to gelatin) and the image material is attached to paper (susceptible to attack by strong acid and benefiting from a mildly alkaline environment); therefore, mildly alkaline (below pH 9.0) housing is beneficial and desired (Ware 1994, 58). Either way, both neutral and mildly alkaline materials are likely to be more alkaline than the print papers. The photographic emulsion can be isolated from the back of the window mat by attaching an undermat of suitable barrier material as appropriate to each photographic type or using thin V-shaped edge strips along the perimeter of the back of the window opening (Phibbs 1997). For cyanotypes, Ware (1999) additionally recommends deep mats that provide an air pocket, as air is necessary to offset fading of cyanotypes while on display.

High humidity and flooding situations that release alkali from the housing materials are of concern. However, if either situation occurs, damage from released alkali may be less of a problem than the softening of photographic emulsions, bleeding of writing, and potential for the establishment of mold (conidia).

The adhesive used to laminate the plies of mat board should be considered when choosing products. Plies adhered with starches or dextrin may be preferred for use with photographic materials over plies adhered with poly (vinyl acetate) emulsion adhesives given recent and ongoing off-gassing problems. Ammonia has been used to neutralize acetic acid in poly (vinyl acetate) emulsion adhesives, so noticing an ammonia odor can indicate its use as a ply adhesive in a laminate board. Neutralizing the acetic acid can be accomplished by adding alkaline materials, such as chalk, to the poly (vinyl acetate) emulsion adhesive.

The cut, beveled edges of the window may be softened with sandpaper (such as on an emery board), with a nail file covered with industrial diamond, or with a Teflon® spatula. Phibbs (1997, 13) prefers the industrial diamond covered nail file, as "sand paper or emery boards may leave grit on the bevel, contaminating it." A softened edge will reduce potential cutting of a soft emulsion surface.

1.5.4.2 Recommendations for mat boards and backing materials

Materials passing the Photographic Activity Test (PAT), ISO 14523:2000 (formerly ANSI IT9.2-1991 and ANSI IT9.16-1993), can be recommended for exhibition and storage use with photographic materials. The PAT tests were originally designed to test quality and suitability of paper boards used with silver photographic images and were updated in 1993 to include color and diazo (microfilm). The PAT tests materials by manufacturing batch, not recipe or type.

1.5.4.3 Commercial paperboard products

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According to Brower (1993, 414), boards that have advertised as having passed the PAT (pre-1993) are:

Light Impressions Westminster ™100% cotton rag
Light Impressions Exeter™ Conservation Board
Light Impressions Non-buffered 100% cotton rag
The James River, Monadnock, Parsons, Rising, and Strathmore paper companies manufacture and supply virtually all the matting and mounting boards available in the United States. Crane Paper Company supplies the Crescent brand.

Brower (1993, 410) lists the following products as 100% cotton fiber boards with an alkaline-reserve suitable for use with photographic materials:
Andrew-Nelson-Whitehead (ANW)-Crestwood Lenox
ANW-Crestwood Gemini
Archivart Extra White
Custom Papers Group Inc. White
Miller Shell White
Rising Warm White, Bright White, Antique
Strathmore Natural
Strathmore White

The following 100% cotton fiber boards without an alkaline-reserve may be suitable for photographic materials, especially for color materials:
Atlantis 100% Cotton Museum Board (TG Offwhite), (initially called Heritage Museum Board TG Offwhite, 1985)
Parsons Brite White Photographic Museum Board (adhered with a poly (vinyl acetate) adhesive) (Phibbs 1997)
Rising White Photomount Museum Board

Atlantis 100% Cotton Museum Boards are specifically manufactured in the United Kingdom for photographic materials. "The 100% cotton boards are sized with alkyl ketone dimer sizing agent and 'lightly' surface-sized with a modified non-ionic farina starch, and have a pH of 7.0", without an alkaline reserve. The board plies are laminated with a V.A.E [ethylene vinyl acetate emulsion] polymer adhesive which contains no plasticizer and is about pH 7.0" (Brower and Wilhelm 1993, 453, 478).

Brower and Wilhelm (1993, 453) found the following 100% cotton colored alkaline reserve boards to have "superior light fading stability" and be suitable for use with photographic materials:

Custom Papers Group, Inc. (formerly James River) Museum Board (Ivory)
Strathmore Museum Board (Brown, Creme, Gray, Green, Natural and Black, recommended when a non-colored undermat is provided)

Boards made with activated carbon or synthetic zeolite (silicate particles) internal molecular traps, such as MicroChamber™ (introduced by Conservation Resources in 1992) and ArtCare™ (introduced by Nielsen & Bainbridge in 1995, using a patent leased from Conservation Resources), remove or reduce the amount of acetic acid, nitrogen oxide, and sulfur dioxide present in the immediate environment (Rempel 1996). These materials can be used for framing and exhibition cases. ArtCare™ is made of alpha-cellulose with the addition of alkaline reserve(s) and synthetic zeolites for a white core. According to the Conservation Resources literature distributed in 1997, some MicroChamber™ materials have natural (activated charcoal) and synthetic zeolites with an alkaline reserve in an alpha-cellulose free of lignin and sulfur. The charcoal side can be powdery, producing black marks and grit.

Lig-free Type II Boxboard (a thin sheet of polyester film laminated between a sheet of lignin-free, alkaline-buffered wood cellulose boxboard on one side and white, non-buffered, near neutral [pH], lignin-free paper on the other, attached with a poly [vinyl acetate] adhesive) and anodized aluminum are recommended as good backing materials (Wilhelm 1993, 520).

Corrugated poly (ethylene) sheets (Corrulite®), double-walled poly (propylene) (Coroplast™, Core-x™), and double-walled poly (carbonate) (Macorlux™) may prove to be acceptable. Sheets made of high-quality poly (propylene) without antistatic, ultraviolet inhibitors are available. The material is prone to static, therefore attracting dust, and has the disadvantage of sharp edges after cutting. It can be used as a backboard in frames and can function as a water barrier if sealed around the perimeter into a frame. A batch of Corroplast™ and Corrulite™ tested by the Library of Congress Research and Testing Division in 1997 passed the Photographic Activity Test (PAT).

Materials deemed suitable for display with Polaroid® prints by the Polaroid Corporation (1983, 33) are:

100% cotton rag museum board
photographic and archival papers
poly (ethylene)
polyester sheeting and sleeves
glass, porcelain, and acrylic plastics

Also cited by the Polaroid Corporation (1983) is the suitability of cellulose acetate. However, research conducted since 1983 suggests this material is unacceptable for use in display conditions. Not recommended as backing materials are corrugated cardboard, gray chipboard, strawboard, binder's board, plywood, Masonite®, and extruded poly (styrene) foam laminates such as Fome-Cor® (Wilhelm 1993, 519). "Cardboard backing material should be avoided as this material can emit harmful fumes. Plywood and pressboard should be avoided, as they contain potentially harmful glues" (Polaroid Corporation 1983, 33).

1.5.5 Hinging and mounting materials

1.5.5.1 Non-adhesive methods

Many photographic conservators are increasingly opting for non-adhesive hinging and mounting methods as more becomes known about the affects of adhesives on photographic materials. Some types of photograph and print materials, such as dye-based inkjet prints, may be sensitive to both water and solvent-based adhesives. Paper and poly (ethylene) terephthalate film, such as MYLAR™ Type D corners can be used for mounting photographs. Polyester may be preferred when the mounting corners will be visible, but must be used with extreme caution, however; it can be too rigid and the edges too sharp, thereby causing physical damage to the photograph. Sharp edges may be rounded with a tacking iron or heat welder. Polyester is often attached with pressure-sensitive adhesive tapes that fail under cold flow conditions (Phibbs 1994). Ritzenthaler, Munoff, and Long (1985, 128) warn "Photographs should not be flexed to position a print within the corners, since such action could break emulsions and possibly crack brittle supports. The safest approach is to attach two corners to the mount board and then to slip the photograph into place; the final two corners should be slipped onto the photograph while it is supported flat on the mount. The corners should not fit the photograph too snugly as this could cause the print to buckle. Very often three rather than four corners will suffice to hold a photograph in place. When dismantling the unit, the corners should be removed from the mount board; no attempt should be made to flex the photograph out of the corners." Be sure to document any information, signatures, or inscriptions on the back before attaching corners to avoid unnecessary un-mounting and re-mounting. Mulberry (*Kozo*) fiber papers can be folded to produce corners effective for holding matted photographs (Phibbs 1994). Paper corners can be held in place with various adhesives and hinging clothes or tapes.

Unmounted lightweight papers, such as early albumen prints, sag when corners of any kind are used (Bertalan and Phibbs 1988). Also, the corner is the weakest part and should not be subjected to stress. Edge strip supports (channels of paper or polyester around the perimeter) can be used to "hinge" some prints. "Z" folded channel strips can be used for lightweight paper or those with designs flush with the edge (Phibbs 1994).

Photographs on thick or distorted supports or mounts can be housed in a sink mat. Photographs in historic frames without matting can be separated from the glazing with spacers (See Phibbs 1994a for diagrams and instructions.).

1.5.5.2 Adhesive choices

Ideally, the use of adhesives in the hinging and mounting procedure should be minimized as much as safely possible. Natural water-based adhesives may not adhere to modern support materials, causing physical damage when the adhesive fails. Wheat starch paste has been used "dryly" to hinge paper-based photographs when moisture is not a problem for the image or support and dextrin has been used with plastic-based supports. Using desiccated blotters (blotters placed on a warm hot plate or heated in a microwave oven to remove moisture) can reduce the drying time in a controlled manner when using aqueous adhesives. Water-based materials and methods should be avoided when hinging ink jet images, especially if the design is flush with or near the edge of the support, as the media is readily water-soluble.

The alternative to water-based adhesives, synthetic adhesives can be irreversible, cross-link, and discolor. Synthetic adhesives, such as Lascaux™ 360 HV and Rhoplex™ 580N, on Japanese papers have been used as temporary hinges for short-term exhibitions. Both adhesive batches passed the Photographic Materials Test (PAT) in 1996, but can have little cohesive strength and can develop cold-flow problems with long-term use. The validity of using the PAT test to determine the suitability of synthetic adhesives has been questioned. In recent decades, commercial companies have developed pressure-sensitive adhesive tape products marketed for repair, hinging, and mounting of photographic materials. Terms such as "inert," "acid-free," "archival," and "passed the PAT" have been used in advertisements. While conservators have not extensively used commercial pressure-sensitive tapes for exhibition mounting, instances may occur where short-term, temporary use seems justified on materials that can withstand subsequent removal of the adhesive tape without damage. It is likely that pressure-sensitive tape products are used on photographic materials in the commercial and private sector. Proprietary product compositions are changed without notice and extensive, long-term testing by the conservation community has not yet occurred.

Likewise, the use of synthetic dry mount adhesives by conservators for mounting photographic images remains controversial. The Society of American Archivists series (Ritzenthaler et al. 1985, 128) states, "Dry mounting, is potentially irreversible, and is acceptable only for expendable copy prints." Dry mounting can also be viewed as the only viable solution for hinging and mounting works that may be water resistant (as with resin-coated or plastic-based prints) or are very large and heavy. Many photographers and conservators have commented on the protective quality of an overall dry mount layer when a poor-quality, acidic wood-pulp mount was originally used. When a good-quality mount is used, the process has been the method of choice and is recommended by conservators for mounting contemporary photographic materials. Prints mounted overall tend to distort less with minor fluctuations of temperature and humidity. Multi-media or large, oversize modern pieces have been displayed in the short term with commercial dry mount and other synthetic adhesives used to attach hinges of paper or polyester webbing (Watkins 1993, 1994). The use of a synthetic adhesive activated under heat should be considered thoroughly before use on materials that did not originally have such treatment. Some synthetic adhesives are known to cross-link with different types of materials; heat has been documented to increase the rate of degradation in materials, and solvents may not be a safe removal option for the image or signatures, photographer's stamps, and other additions. Mounting resin-coated prints to rigid supports, such as aluminum, that remain impermeable to organic solvent treatments, limits reversibility and removal attempts (Watkins 1993, 1994).

For exhibition and transport the Polaroid Corporation (1983, 29-30, 33) recommend the following: Use die-cut corner mounts in a good-quality paper board or archival paper corners that are held to the backboard with archival library linen tape, or mount Polaroid® black-and-white and Polacolor® prints. On mounting, "integral films should not be heat mounted. Polaroid photographs should not be subjected to temperatures higher than 180°F (82°C) and should not be left in the heated press for longer than 30 seconds. Kodak [Type] 2 Dry Mounting Tissue™, Ademco Low-Temperature Dry Mounting Tissue and Seal Low Temperature Mounting tissues are satisfactory. Lamin-All, from McDonald Photo Products, Inc., is a suitable liquid adhesive for mounting Polacolor® prints. It can be used either cold or under heat. When you mount Polaroid® coated black- and-white prints place the materials into the mounting press so that the mounting board faces the heated surface of the press and the print faces away from the heated surface." Since 1983, some conservators have expressed concern over the use of heat in part because of the complexity of dye diffusion transfer materials. The long-term, potentially damaging effects from heat should be considered prior to dry mounting Polaroid® material, especially unique work.

1.5.6 Framing materials

1.5.6.1 Preferred framing materials

Anodized aluminum frames are recommended instead of wood. As Wilhelm (1993, 511) explains, they "are inert, inexpensive, lightweight, and unaffected by moisture fluctuations. Stainless steel and brass are also safe, but are expensive and heavy." The Polaroid Corporation (1983, 33) agrees citing aluminum, stainless steel, materials coated with baked enamel, and epoxy powder-coated welded aluminum frames as inert construction materials.

1.5.6.2 Wood and wood composites

Ideally, wood and wood composites should be avoided when framing photographic materials. Wood and wood composites can release acetic acid, formic acid, propionic acid, isobutyric acid, alcohols, and formaldehydes in varying amounts. According to Cecily Grzywacz, scientist at the Getty Conservation Institute (1999), "The specific acidity of a wood board is dependent on the felled tree. In other words, there is variance within species." In addition, some woods may have been processed or treated with insecticides that have undesirable effects (Craddock 1992, 24). Particleboard and plywood are manufactured with urea-formaldehyde, melamine-formaldehyde, and phenol formaldehyde adhesives that can off-gas "phenol from resin, hydrochloric and other acids from hardeners, ammonia, hexamine or melamine from the retarders" (Raphael 1991, 7). The Polaroid Corporation (1983, 33) recommends that for Polaroid® material, "plastic and wooden frames should be avoided."

Economic costs and aesthetic concerns may occasionally outweigh the risks of potentially damaging side effects from wooden frames. Wilhelm (1993, 511, 534) conceding that wood will be used despite the risks, mentions well-dried maple, birch, or basswood as preferred for use with photographic material. When contemplating the use of wood near photographic materials, the following characteristics should be considered (Anderson 1991; Raphael 1991; Craddock 1992; Greenfield n.d. [ca. 1992]):

<u>Least acidic woods</u>: Aspen, American (Swietenia group) or African (Khaya group) mahogany, balsa, basswood, birch (not yellow), eastern hemlock, sweet gum, yellow poplar, walnut, Sitka spruce, and tropical iroko, ramin, and obeche woods

True mahogany is considered the best wood choice, however, it is expensive and difficult to obtain. Several types of native mahogany species are on endangered species lists, like the Convention on International Trade in Endangered Species (CITES). Introduced mahogany species may be exempt from the endangered species restrictions. Current availability and source origin should be checked before use.

<u>High acidity or corrosive woods:</u> ***<u>DO NOT USE!</u>*** Ash, steamed beech, yellow birch, butternut, red and western red cedar, sweet chestnut, cypress, elm, Douglas fir, hickory, larch, oak (new or well seasoned), particleboard, pecan, pine (white, southern yellow, loblolly), plywood, redwood, spruce (not Sitka spruce), and teak.

Yellow pine is close to neutral pH, but gives off other organic gases that are harmful to materials other than metals (Craddock 1992).

Newly made wooden frames should be coated at least one month to six weeks prior to framing to seal pores, create a more uniform film coating, and off-gas volatile diluents. The coating chosen must not contain or release pyroxylin (cellulose nitrate), formaldehyde, phenols, acids, ammonia, hexamine, melamine, or peroxides (Raphael 1991). Paints seen as suitable, such as acrylic paints, can obscure the wood, negate the aesthetic look desired, and may be only partially effective in preventing acidic off-gassing from the wood. Latex paint is not a vapor barrier and may also contain bacteriocides (Greenfield n.d. [ca. 1992]).

Wooden frame rabbets and interiors may be blocked with foil-backed adhesive tapes, aluminum, nylon or poly (ethylene) films and barriers (such as Rosco Cinefoil™ and Marvel Seal 360®) to reduce potential off-gassing during short-term displays. In addition, sealing the glazing and mat as a unit with a foil-backed adhesive tape before framing can help reduce off-gassing from wooden frames and outside sources from reaching the photographic material. Materials with zeolite molecular traps or activated carbon may absorb potentially damaging gasses from wooden frames and environmental sources. Carbon can re-emit absorbed contaminants during long-term storage, but this is not likely to occur over the course of an exhibit.

1.5.7 Construction: Cases, and packing and crating materials

1.5.7.1 Considerations for display cases, packing materials, and crates

Light intensity at the surface of the displayed item should be accurately measured and should conform to the specifications for the object. Ritzenthaler et al. (1985, 127-128) warn: "Generally light sources within exhibit cases are not necessary and should be kept off, or the units should be removed entirely, since they often emit too much light and can contribute to an excessive build-up of heat. If conditions within the exhibit area require lights within cases, however, fluorescent tubes are recommended because they will not give off as much heat as incandescent bulbs. Fluorescent tubes must be covered with ultraviolet filters (or low ultraviolet emission tubes should be used). Diffusion panels also should be incorporated into the light units to ensure even illumination of the entire case and to keep any one object from receiving too much light. Lights within cases should be on only when viewers are present. Other light sources in the exhibit gallery must be evaluated as well. Windows should be glazed with ultraviolet filtering sheets, and filters should be placed over all fluorescent tubes. Beams from spotlights or track lighting should not be aimed to fall directly on photographic images. To diminish problems posed by light within the exhibition gallery, exhibit cases can be glazed with ultraviolet filters."

Temperature and humidity within the case should be maintained at stable and reasonable levels. "The most economical means to accomplish [recommended requirements for temperature and humidity] is to make sure the exhibition cases are placed in areas that are temperature and humidity controlled. Cases should not be airtight, but should allow for ventilation so that conditions within the cases will equal those in the exhibition hall. Filters may be placed over air holes to prevent dirt and dust from entering exhibit cases" (Ritzenthaler et al. 1985, 127). Hygroscopic lining and packing materials (e.g., paper, boards) that adsorb and desorb can buffer items against small moisture changes. Lateral case entry design is preferred over vertical (e.g., five-sided acrylic vitrine) to help maintain relative humidity (Raphael 1991).

Materials off-gassing in microclimates (such as cases) can have a far more deleterious effect on photographic materials than overall air quality present in a building because of entrapment and buildup of pollutant gasses (Green and Thickett 1994, 4). To most effectively retard or reduce the likelihood of chemical damages, it is recommended that only the best-quality materials passing the Photographic Activity Test (P.A.T.) be used. Also, ensure that materials used in conjunction with photographs on exhibit are of good quality before all the activated-carbon filters in a case or the air handling system are changed. Fabrics woven with activated carbon can be beneficial in reducing the possible buildup of gaseous contaminants. However, charcoal cloths can contain poly (vinyl chloride) components, and direct contact with photographs should be avoided.

All construction materials, finishes, paints, fabrics, and sealants must be non-reactive with photographs and must be fully cured (minimum three weeks) prior to use. Testing prior to use and installation is encouraged. It is a good idea to allow space between the case and wall, especially exterior walls (Raphael 1991).

Plywood used for building exhibition spaces or for cases should be laminated with phenol-formaldehyde adhesives, as these appear to be more stable than the urea-formaldehyde adhesives (Anderson 1991), or melamine formaldehyde (Glaser 1994, 4). American Plywood Association (APA) material is certified to be made with phenol-formaldehyde resins (Craddock 1992, 25). Wood comes in many grades of quality; preferred are birch plywood made with phenol-formaldehyde adhesive (exterior grade with moisture-proof adhesive), marine grade (made with moisture-proof adhesive with no interior voids), type one (strongest), AA or AB (best face quality without knots on either side) or Medex (particleboard with phenolic resin matrix). It is becoming increasingly difficult to obtain non-processed, non-laminated woods (see section 1.5.6.3.). Honduras mahogany, balsa, basswood, poplar, and Sitka spruce, with a minimum of three coats of polyurethane, have been used in exhibition cases.

Plastic frames and vitrines can absorb and retain pollutants from the materials stored within them. Plastic vitrines, especially "poly (carbonate) and poly (methyl methacrylate), should not be reused indiscriminately" (Fenn 1995). Therefore whenever possible, virgin plastic vitrines and frames should be used with the most reactive types of photographic materials. Plastics that are deformed, discolored, or crazed should not be used.

Non-adhesive techniques are best for constructing cases and interior supports. Support materials such as cradles, wedges, straps, and snakes may be necessary for the safe display of albums and books with photographic material. Straps used to hold albums and books open should be made of poly (ethylene), poly (propylene), or poly (ethylene terephthalate) (MYLAR® Type D, Melinex® 516) without additives. The thinnest and "softest" material for the support needed is best. Straps should be used with caution and away from image areas when possible, as strap edges can cause physical damage. However, set too loose, the straps may be ineffective. Explicit instructions should be given to handlers and installers using straps.

1.5.7.2 Suitable materials for constructing exhibition cases and traveling cases

The following lists are based on information in Miles (1986), Raphael (1991), Craddock (1992), Greenfield n. d. [c. a. 1992], Wilhelm (1993, 511), and Hatchfield (1996):

Adhesives: silicone, acrylic adhesives (3M #415), poly (propylene) and poly (ethylene) hot-melt adhesives, two-part epoxy or moisture-cured poly (urethane) with several weeks of airing

Cases, traveling: ribbed aluminum, fiberglass, or molded poly (propylene) with sturdy handles and locks

Fabrics: unbleached, undyed, washed cottons or linens, polyester, cotton-polyester blends, fabrics without flame retardants, surface coatings such as permanent press, sizing, or dyes

Filters (Sorbants) (Suitable for cases, but do not put these materials in direct contact with photographic materials): activated charcoal, 4% potassium permanganate on neutral activated alumina (Purafil™), molecular sieves (zeolites), silica gel

Gaskets: silicone, poly (tetrafluoroethylene) (Teflon™), acrylic felt

Glazing: glass, many glass laminates, acrylic sheeting, poly (methyl methacrylate) (Plexiglas™)

Humidity control: silica gel, dry desiccant salts

Packing material, short-term for crates: poly (ethylene) foam (Ethafoam®, Volara®), poly (propylene), poly (butylene)

Paints, coatings, and varnishes: acrylic paint, oven-baked enamels and lacquers, latex paints without bacteriocides, water-based aliphatic urethane (3 coats minimum), Acryloid B-48N™, B-72™, B-67™

Plastics and films: acrylic (Lucite™), poly (ethylene terephthalate) (Mylar Type D™, Melinex 513™), high-density and low-density poly (ethylene) (Ethafoam™, Volara™), poly (propylene), poly (carbonate) (Lexan™), poly (styrene), poly (methyl methacrylate) (Plexiglas™), metal laminated films (Corrosion Intercept™, Marvelseal™, aluminum poly [ethylene] nylon foil)

Metals: anodized aluminum, anodized steel, chrome-plated steel, nickel-plated steel, powder-coated baked enamel stainless steel (when sufficiently heated and fully cured)

Supports: Tycore™ (paper honeycomb panels), aluminum honeycomb panels, Alucobond™ (aluminum/poly (ethylene) panels)

Wood, crates: plywood (laminated with phenol-formaldehyde or melamine formaldehyde adhesive)

1.5.7.3 Unsuitable materials

The following lists of unsuitable materials are based on information in Miles (1986), Thomson (1986, 156), Greenfield n. d. [c. a. 1992], and Wilhelm (1993, 511):

Adhesives: protein-based glues, cellulose acetate resin, cellulose diacetate resin, cellulose nitrate resins and adhesives, most pressure-sensitive tapes, spray adhesives, formaldehyde-based adhesives, melamine-based adhesives, urea-based adhesives, polysulfide adhesives, poly (vinyl acetate) emulsion

Fabrics: wool, wool felts, fire-retardant products on cloth

Gaskets: vulcanized rubber and rubber derivatives, poly (vinyl chloride), poly (urethane) foams

Humidity control: open-pan liquid desiccant salts

Packing material: urethane, poly (styrene), poly (vinyl chloride) foams

Paints, coatings, and varnishes: drying oils, oil modified, and oil-based paints including alkyds and enamels (dried at normal temperatures, not oven-baked), lead based paints, one-component poly (urethane) varnishes (Varathane™) and resins, epoxy ester paints, aluminum paints, silicone paints

Plastics and films: cellulose nitrate, poly (vinyl chloride), ultraviolet radiation absorbing surface finishes (laminates appear to be all right)

Wood: oak (especially), yellow birch, beech, teak, plywood, particleboard, Formica®-covered plywood and particle wood, Masonite®, Medite I™ (urea-formaldehyde resin), and Medite II™ (formaldehyde free, has acetates), MDO (medium-density overlay) (see section 1.5.6.3)

1.6 EXHIBITION TECHNIQUES FOR PHOTOGRAPHIC MATERIALS

1.6.1 Perceptual adjustments

Human brains perceive color in light and adjust to available light. Understanding how the human brain and eye process photons can be helpful when designing lighting. The optimal blend is safe light levels for preservation and sufficient light levels for color rendition.

1.6.1.1 Using lighting situations

Different types of bulbs (e.g. tungsten, fluorescent, etc.) produce different spectral energy distributions. It is important to choose a bulb that emits low levels of the wavelengths that are most damaging to the types of photographs being displayed. For example, low-UV-emitting bulbs are available. "Color temperature specifies only the color and saturation of the light. There are many spectral energy distributions which yield the same color temperature." (Brill, 1980, 18) The interaction of color temperature and footcandles (lux) is also deserving of consideration. Higher wattage bulbs produce more footcandles (lux), thereby causing more damage. The human eye will tend to perceive lower levels of illumination as balanced "white" illuminance even if the light is "warmer", that is to mean, at a lower color temperature. The infrared output needs to be monitored as lighting becomes warmer. While most people prefer warm lighting situations, Lull's (1999) experience indicates that cool lighting can be offset with warm tungsten light sources to balance the exhibit space without substantially increasing the footcandle (lux) output, yet making the exhibit area easier on the eye. Placing the lighting units as far away from the photograph as possible will reduce the impact of heat. Exhibition lighting for photographic materials should only be turned on when it is needed, thus limiting the exposure time for the items on display.

Reilly (1986, 105) notes, "people coming from outdoors or a brightly-lighted part of a building need up to several minutes to fully adapt to low levels of illumination. Adaptation may be encouraged by routing visitors who are approaching the exhibition area through rooms and corridors with successively lower light levels." Once in the darkened room, it is advised to direct illumination to the vicinity of the hung item. Reilly (1986, 105-6) additionally recommends illuminating the exhibition area evenly and avoiding very light or very dark walls. Bouncing lighting off a white ceiling can evenly illuminate a smaller, darkly painted exhibition room.

Not all exhibition spaces are restricted for viewing purposes. Ritzenthaler et al. (1984, 128) notes that light levels could be lowered substantially without affecting other activities for exhibits in reception areas or reading rooms. She and her co-authors also suggest, "notes posted in exhibition areas explaining the reasons for reduced light levels will help to generate understanding and support on the part of the visitors."

1.6.1.2 Using wall and mat colors

Increasingly darker shades of wall colors (e.g., going from brilliant white to a medium gray) can be used in conjunction with successively decreased illumination to provide for low light levels. Small or "intimate" exhibition spaces with low light levels can appear more inviting by using wall colors with warm undertones, which are more soothing and relaxing on a subliminal level. Wilhelm additionally notes (1993, 610) that "dark or black walls and ceilings should be avoided since most people do not like the 'cave' feeling of darkly painted rooms." A light-colored ceiling will make a room appear brighter and larger (see section 1.6.1.1).

Light-colored mats against dark frames set against darker wall colors will "spotlight" pictures. Wilhelm notes (1993, 610) that the "visual appearance of the photograph is enhanced when the surrounding areas are darker than the photograph."

1.6.1.3 Reducing glare

Picture glazing and glossy wall paints can reflect spotlights intensely, producing viewer eyestrain. The use of neutral density glass, acrylic sheeting, or antireflective glass can help make dark photographs with glossy surfaces easier to see. Wilhelm (1993, 610) advises avoiding white or light-colored walls "since the bright surfaces will have the effect of reducing the apparent brightness of the print and will increase glare on the glass over photographs on opposite walls." Anti-reflective (AR) glass can help make a dark photograph with a glossy surface easier to see.

Sunlight and "other sources of bright light should be eliminated in photographic display areas," advises Wilhelm (1993, 612) as "uneven lighting and difficult viewing conditions are created during daytime hours." The varying, unregulated light levels can also significantly increase the footcandle (lux) and ultraviolet level. When windows cannot be avoided, Wilhelm advises reducing the ultraviolet radiation through windows by using ultraviolet filters such as Lucite® SAR UF-3 or Plexiglas® UF-3.

1.6.2 Display techniques to reduce light exposure

1.6.2.1 Covered frames and cases

Veils, curtains, drapes, and shrouds can be constructed out of opaque, dense-weave, light-obstructing fabrics such as heavy twill, velvet, or velveteen. Doubling the fabric or backing the cloth with Tyvex® or a similar material provides additional shading of the object. When lifted for viewing, a dark-colored liner will reduce glare. Cloths can be weighted with a rod or bar (e.g., Plexiglas®), light drapery weights, or fishing weights as appropriate to ensure coverage of the photograph and to facilitate easy lifting of the cloth, but also may increase the likelihood of being left open by visitors. Advanced designs can incorporate pull cords to open and close a protective cloth or drape. Designs should allow for easy access for visitors in wheelchairs. Shadow box construction can help support a protective cloth and provide additional shade from ambient light from the edges. Costs include fabrics, weights, perhaps cords, and labor for construction, making this a potentially inexpensive, yet effective option for reducing light exposure.

1.6.2.2 Closed cases

Drawers have been used to house and display photographs. Care must be taken to ensure that the photographs are secure inside the drawer so that the motion of opening and closing the drawer does not scratch, jar, or otherwise adversely affect the photograph. Design of smoothly operating drawer runners that pull out flat (do not tip), have stops (so the drawers cannot be removed by visitors), and have adequate bumpers (to reduce jarring) is essential toward this end.

Lighting for display cases must be chosen carefully. Many light fixtures and ballasts give off considerable heat and should not be located near photographic material. One alternative is to design an isolated lighting chamber lined with heat-reflecting glass and double-glazing (Raphael 1991, 12). An alternative to conventional lighting design that has lower heat and ultraviolet output is fiber optic systems.

1.6.2.3 Metal screening and neutral density filters

Metal screening and neutral density filters placed directly in front of the illumination source reduce the light intensity (see section 1.5.2).

1.6.2.4 Dimmers

Thomson (1986, 207) notes that dimmers are energy efficient because they "use phase control circuits which alter the phase between current and voltage." However, for photographic materials, Wilhelm (1993, 609) notes the limitations of dimmers beyond "making minor adjustments in light intensity." They "should be used with restraint, since the color temperature of the light is lowered, and the light becomes progressively redder (increasing infrared output), as the light intensity is reduced below normal. Low-voltage lamps operated by a transformer require special types of dimmers, and quartz halogen lamps cannot be dimmed beyond a certain point without interfering with the halogen cycle." The amount of ultraviolet light that can be reduced will vary depending on the type and original spectral output of the bulb being dimmed. The costs vary by brand and quality but are comparable to timers and motion detectors.

1.6.2.5 Timers

Timers provide illumination as needed through viewer activation of switches or push buttons that thereby limit the exposure times for an item. Timers are energy efficient if tungsten light sources are used. In heavily attended exhibitions the lights end up being on much of the display time, although less than normal. In many museums, the gallery lights are turned on to allow for security, maintenance, and janitorial functions for many more hours than those open to the public. Diagrams instead of written instructions are beneficial for visitors who do not read the local language. Location of devices for activating the timers should be set at levels that can be activated by visitors in wheelchairs. The costs vary by brand and quality but are comparable to dimmers and motion detectors.

1.6.2.6 Motion detection, occupancy sensors, or "light on demand"

Motion detectors provide lighting as needed without the public having to manipulate switches or read or interpret directions. A darkened gallery may be interpreted by many as a closed gallery, however. Signage at the gallery entrance is recommended to welcome visitors and briefly explain the lighting. Additionally, they meet access standards set by the American with Disabilities Act (USA). They are ideal for energy efficiency and restricting the period of light exposure to an item. However, in large exhibitions, the lights will be on much of the display time. The detectors can also provide an impromptu game for children, though attentive guards should be able to reduce unnecessary use of this kind. Motion detectors can be purchased in conjunction with timers. The costs vary by brand and quality but are comparable to timers and dimmers.

1.6.3 Lighting techniques for objects

1.6.3.1 Transmitted light illumination

Viewer-activated light boxes can be used for sensitive or transparent material, such as waxed, salted paper negatives, thereby limiting light exposure. Viewer-operated fiber optic mats have been used to illuminate wax paper negatives and transparencies from the reverse.

1.6.3.2 Double-sided images

Poly (ethylene terephthalate) (MYLAR® Type D, Melinex® 516) encapsulates and double-sided mats and frames have been used to support items during illumination. Freestanding plinths and false walls built perpendicular to primary walls (along with two-sided frames and window openings) are useful for viewing translucent or double-sided images. They can be illuminated from one side or by reflected light from below.

1.6.3.3 Daguerreotypes

Daguerreotypes are best viewed with "single-source" directional light illumination coming from a 45° angle to the place surface. This arrangement will allow the reflected light to pass to the side of the viewer; otherwise only glare or a mirror effect will be seen. Overhead illumination descending across the horizontally oriented polish plate marks will create a haze of scattered light that can obscure much of the image.

1.6.4 Security techniques

Nineteenth-century photographic formats, such as daguerreotypes, ambrotypes (positive collodions), tintypes, and cartes de visite (CDV) are often small. Added care should be taken to ensure that these materials are mounted securely, displayed in cases, or otherwise secured against the possibility of theft. Exhibit cases should have locks or barrier devices to prevent unauthorized access. Frames can be secured to the wall to reduce damage from theft or minor earthquake.

Large, oversize contemporary photographic materials may be collage composites or composed of easily scratched materials (e.g., plastics). Real and psychological barriers such as platforms, floor wedges, and protrusions can be used in the display area to restrict public access to the surface of photographs when glazing is not practical or conflicts with the photographer's intent.

1.6.5 Rotation, replacement, duplication, and facsimiles

1.6.5.1 Using rotation, facsimiles, and duplicates

Similar objects can be used in rotation when use of the original is a necessity. For didactic or historical purposes, it may be wise to use facsimiles or copies, especially when an image is being used for its information, rather than its artifactual value or when exposure conditions cannot be controlled to preclude damage. Facsimiles should also be used if security is limited. Wilhelm (1993, 241) believes that "facsimile color copies should be made before a fading or staining limit is reached." Facsimiles of album pages can be made in order to display several images from the album at once. With any methodology used in creating a facsimile, it is essential to clearly and permanently label the facsimile as such.

Some types of photographic facsimiles can be made commercially by local businesses such as copier, graphics, or aerial photographers (check with local or regional highway departments). Prepare the original material for reproduction by providing a rigid backboard and sleeve or encapsulation of the material in polyester film. (Potential glare from the polyester film can cause difficulty for the photographer, unfortunately.) Stay with the materials while the order is being processed. Carefully consider the risks posed to rare, important, or vintage prints when commercial firms handle them. Also, consider that photocopying processes can cause damage from light exposure or handling.

1.6.5.2 Types of reproductions

Authentic historical methods can be used to fabricate new examples. For example, salted paper prints can be newly made. Modern materials can sometimes be used to create convincing substitutes. For example, autochromes can be reproduced by color transparencies using a digitized color-analyzing system. Facsimiles of most photographic processes, complete with replication of the damage or aging effects, can be successfully made. Duplication processes currently available can produce good-quality facsimiles with relatively good light stability. This technology is rapidly changing, and the development of alternative techniques is inevitable. Please consult current printed sources and websites.

1.7 TRAVELING EXHIBITIONS AND LOANS

1.7.1 Considerations and loan agreements

The potential for physical damage from handling increases with the frequency of exhibition and number of venues. Damage can occur from handling during preparation, installation, de-installation, transportation, or neglect during holding periods and locations between sites.

A "Standard Facility Report" is available from the American Association of Museums (AAM). This document and others like it can be helpful in determining suitability of sites for display of photographic materials. Specific requests for photographic materials can be made by item and, generally, are negotiated before loan agreements are reached. "Specific requests for photographic materials" might include materials for cases, lighting type and configuration, or temperature and relative humidity ranges permissible. Also potentially negotiated are the loan fees, insurance, duplication rights, couriers, method of transportation, and packing parameters, among other concerns.

It will be possible to determine whether a venue to which an exhibition is traveling has suitable air purification systems by obtaining the facilities report or speaking with the institution's building maintenance crew. Very few institutions, however, have standards on air quality at present.

1.7.2 Documentation of condition

Damage assessment logs or notebooks with all the images represented are essential for multi-venue travel. For easy assessment of condition for non-conservation personnel, note existing damage on a visual printout of the image or use poly (ethylene terephthalate) (e.g., MYLAR® Type D, Melinex® 516) overlays or sleeves with existing with a permanent film marking pen (e.g., Sharpie®, Light Impressions™ 2631, etc.) over outlined scale images, photocopies, or duplications. Placing each report in a polyester sleeve will keep written information with a visual duplication or overlay. Checklists are easier than forms with only blank spaces for comments. Some institutions request that copies of the assessment logs be returned to them at each venue. The person inspecting the condition upon arrival should also check condition upon departure. For visually oriented persons, visual observations can be more accurate than written information. Likewise, photographic documentation before travel can be extremely useful as a comparative tool.

Possible items to include in the documentation:
institutional name, address, and phone number (owner/contact person)
name of show and venues (name, address, and phone number)
crate number and size
crate/package construction and instructions for safe disassembly
identification number of item
artist's name
title of item
date or era of item
medium/format
dimensions of item
inscriptions on item
housing (kind of hinging or mounting, matting, frame, case, etc.)
picture (photograph or photocopy) of item
copy with translucent or transparent overlay with damages noted
area for condition: incoming
    venue name
    date

signature of inspector
area for condition: outgoing
venue
date
signature of inspector
record of monitoring equipment data readings (if monitoring equipment is included)
A template for each item should be made if they will be tested with monitoring equipment such as a densitometer.

Listing one item per page is useful. Concise descriptions are preferred over general assessments. (e.g., "one quarter-inch tear along upper right edge" versus "good condition, minor damage"). It is advisable to note what is visible after matting and framing and to make particular note of any conditions that could occur during travel. Condition reports should be written so that non-conservation professionals can follow and understand them. During a traveling exhibition, someone unfamiliar with the item at another venue should be able to determine whether any change or damage has occurred during transit or exhibition time. Visual documentation included with written descriptions is helpful. Possible contents of a travel log and checklist can note loss, tear, abrasion-rub, crease, stain-soiling, handling marks, accretions, smudge, marring-surface sheen, mirroring, scratches, scar-dent, rippling-wrinkling, distortion-buckling, broken glass, hinge failure, insect infestation, moisture and mold damage, etc., along with denoting the location of damage and date noticed.

1.7.3 Preparations for transport

1.7.3.1 Glazing

For transit, acrylic glazing or shatter-resistant glass (a laminate of glass and plastic) is recommended over single sheets of glass (Phibbs 1996). Glass can break easily, and even the smallest of shards can extensively cut and abrade many photographic materials. Acrylic glazing is less likely to crack and break during transit; it should not be taped. Acrylic glazing can be subject to horizontal deflection. As the sheet size increases so does the potential bowing and sagging. A minimum of 3 mm (0.118 inch) thickness in acrylic sheeting is recommended. Transporting materials framed with acrylic glazing vertically, rather than flat, will reduce the risk of the glazing contacting the photograph, but will increase the strain on mounts and hinges.

Face-mounted photographs pose handling challenges. Most of the damage observed in collections is physical in nature and was inflicted during handling or transportation. Poly (methyl methacrylate) (PMMA) sheets are easily scratched, and prints can be physically damaged from the reverse. Therefore, it is imperative that extreme care be taken when handling face-mounted photographs, especially as these are often large and heavy. The addition of a sheet of clear, corrugated poly (propylene) to the back of the photograph is suggested for prints without any backing. This lightweight material provides a backing protection that does not interfere with the visual aspect of the print. As with other plastic glazing, PMMA should not have pressure-sensitive tape applied to the face.

A sufficiently deep separator from the glazing, whether a mat or secured spacers, can ensure that abrasion, ferrotyping, attachment, and other damages do not occur during transit.

Do not use pressure-sensitive tapes over the cover glass of cased photographs, as is often recommended for transporting items framed under glass. If the cover of a cased item is missing, a cover should be created to reduce the chance of glass breakage from possible impacts and shocks during transportation. Covers can be made of numerous rigid supports such as museum board or good-quality corrugated boards.

Convex glass presents special transit problems. Two solutions are a form-fitting Ethafoam® support for the glazing and unframing for separate transportation.

1.7.3.2 Matting

Float-matted photographs (all edges are visible within the window mat) should be reinforced (either with hinges or with photographic corners) at all four corners, most effectively at the top and loosely at the lower left and right sides. This arrangement helps equalize travel stress and jarring from all four directions, and it prevents the photograph from shifting into the edge of the mat window or lifting because of a potential electrostatic charge of the plastic glazing.

Images larger than 16 x 20 inch (40.6 x 50.8 cm) need an 8-ply mat or at least a 1/4 inch (0.6 cm) spacing from the plastic glazing, more if the photograph is not flat nor mounted. Very large images need much more space due to the capacity for plastic glazing to bow and flex with travel vibrations and backings to bow with humidity changes.

Photographs that have heavy paper supports or are mounted to rigid supports should be placed in sink mats (Bertalan and Phibbs 1988) to provide necessary support and help reduce the danger of the item being crushed or abraded during handling or transit.

1.7.3.3 Framing

The order of materials for framing is: glazing (plastic for travel; see section 1.5.3), minimum 4-ply window mat and backboard (non-lignin, alkaline or non-alkaline as necessary, "rag," museum, or zeolite molecular trap board), secondary rigid support, seal around the housing perimeter edges before placing into the frame. Hardware holds the matting package in the frame, and the back of the frame is sealed with a dust cover and moisture seal (polyester film, anodized aluminum, etc.) and hanging hardware (if necessary).

Metal frames seem to travel better structurally than wood frames, whose corner joints may weaken from ordinary, unavoidable knocks in handling. Good-quality wood frames with reinforcing members (racks) can be sturdy, however. Even with the safest handling and padded travel crates, unsightly wear and scratches on frames and plastic glazing can be expected (see section 1.5.6).

Large, heavy, oversize, or panoramic frames may need the additional structural support of strainers and stretchers on the reverse. Materials chosen for structural supports should be of the same quality as chosen for the rest of the frame package.

In choosing framing materials and preparing sizes of mat boards and glazing, the potential factors of nominal shrinking and expansion should be taken into account. Wooden frames and mats and boards can expand as the humidity increases and contract as the humidity decreases. Phibbs contributed in 1997, that acrylic sheets can expand as the relative humidity level increases. Room should be allowed for the fluctuation in size of interior and exterior components without jeopardizing the sealing components of the matted and framed package.

Wilhelm (1993, 517) recommends against creating venting holes for framed materials. Materials used for framing should be of sufficient quality not to need venting or off-gassing, and holes in the dust cover can allow dust, insect infestation, pollution, and more rapid moisture fluctuations to occur. A barrier, divider, or separation (such as a window mat) between the photographic material and glazing should provide enough space if condensation occurs on the glazing.

1.7.3.4 Wrapping

A temporary vapor barrier wrapping, such as Dartek™, around the framed item can help reduce and slow down inherent changes in relative humidity as photographic material moves from one climatic area to another.

1.7.3.5 Packing

The goals of a good transportation package are to provide physical protection (cushioning, moisture-barrier, etc.) and chemical protection (from pollutants, interior off-gassing, etc.). Packing design and written instructions with the case can minimize damage possibilities. Packages not destined for crating ("soft-packing") require a stable temperature environment throughout transportation.

Reducing the volume of air within inner packages reduces changes in the equilibrium moisture content (EMC). Saunders et al. noted that minimizing EMC changes reduces possible adverse effects from changes in relative humidity fluctuations in the exterior or interior environment (RCL 1995). Placing hygroscopic materials in the interior package will help reduce changes in the interior EMC. Materials that are not moisture absorbent, such as metals, may be damaged by sudden temperature and moisture changes. Fluctuations can be reduced with the addition of materials such as boards, paper, or silica gel (Richard et al. 1991, section 4) that will absorb and desorb moisture in the environment.

Large and oversize photographs on flexible bases may have to be rolled for transport. It is best to use the largest diameter roll (minimum 6 inches or 15.2 cm) that can be safely handled and to roll the photograph in the direction of the existing curl. Rolling the photograph with the image face-in on the tube is traditional with paper supports and helps protect the image from handling damage. Rolling the photograph with the image face-out on the tube is traditional with cloth supports and prevents compression of multi-layered surfaces whether on cloth or paper. Wrapping the tube and separating multiple photographs on the same roll with an interleaving material can further protect items, but must be chosen with care. Soft emulsion layers can be scratched or burnished by abrasive surfaces, such as with silicon-release poly (ethylene terephthalate) (e.g. MYLAR® Type D, Melinex 516). In addition, paper can be made translucent through beating and processing or through the addition of additives (waxes, oils, etc.). In the past, glassine made translucent by chemical additives has been known to adversely interact with photographic processes while in storage and under high humidity conditions. Rolled photographs should be suspended within a box to prevent damage from the weight of the roll resting on the photograph.

Tests performed by Robb (2000, 75) "seem to indicate that sealing ink jet prints in humidity stable packages can reduce short-term risk from high humidity environments"; a situation that may be encountered during travel between venues.

1.7.3.6 Crating

Closed crates provide the best physical protection for photographic materials during transit. Traveling cases made from ribbed aluminum, fiberglass, or molded polypropylene, complete with sturdy handles and locks are safe for transporting photographic materials. Crating with inner cases improves insulation and mechanical protection during transportation, thereby minimizing damage. For example, cased photographs are easily shipped within carved Ethafoam® (or similar inert) packing materials within a case or crate. Paul Marcon and Thomas Strang of the Canadian Conservation Institute have developed "PadCAD Cushion Design" software to determine adequate packing protection. The software is available through CCI Publications. Air envelopes can be used to offer a soft-pack protection on framed items prior to casing. Bubble wrap may not be suitable for long-term packing and storage, as it may be coated with poly (vinylidene) chloride

(PVDC), added to prevent deflation of the bubbles through the poly (ethylene). Bubble wrap without PVDC has a tendency to deflate when held against a flat item, thereby negating usefulness.

Crated material should "ride" face up or vertically in the orientation of hanging and labeled thus. Crating should be secured in the interior of the transportation mode so it will not bounce or move around during transport (Richard et al. 1991, section 5).

The following are essential for multi-venue travel: padded, cushioned, slotted crates, or trays fitted to the frames, clearly labeled with which frame goes in each slot, crate lists on the lids, and condition notebooks with all the images represented. Sensors included in the case can indicate if environmental conditions have caused or contributed to any changes noticed with the photographic material (see section 1.7.5). Data loggers can be programmed to monitor relative humidity, temperature, light, and specific pollutants. Special indicating cards for relative humidity can be used in traveling cases if an indication of humidity is all that is required. The patches on these cards change color as the humidity level rises, but do not "de-color" at lower humidity levels. Freeze indicators are also available. Some shock and drop indicators are designed for resetting, so they can be reused. The readings are given as "G" forces, with the most sensitive ones available at 5G up to 100G designed for "heavy" products. Likewise, tip and tilt indicators are available. These change color when crates are placed on their sides or upside down but seem to tolerate tilting of crates to put on carts and hand trucks. All these sensors provide an indication of an event that has already happened. Many cannot indicate a precise location along the route when the event occurred, however, should that be deemed necessary information. It is important to remember that the sensors cannot mitigate the potential problem before it occurs.

1.7.4 Handling of objects

Those responsible for objects should identify the personnel who will be handling the materials, such as in-house or contractors, conservation professionals, preparators, exhibition handlers, and carrier and transport companies. Individuals preparing and transporting work for exhibition should be familiar with any unique or special handling demands or requests of photographic materials. Routine procedures for handling photographic materials include use of clean gloves, especially when handling metals and plastics, as these corrode and scratch easiest. Personnel should maintain clean hands as well, especially when wearing fabric or woven gloves, to reduce hand oils and sweat. Space and furniture needs are similar for all preparation areas: clean, dust-free rooms, clean, cushioned tables, uncluttered floor space, trays and cups to keep tools out of the way, and separate, designated areas for storage of packing materials and the pieces to be packed. When possible, crates and packages should be allowed to acclimatize for a minimum of 24 hours before unpacking.

1.7.5 Means of transportation

Whether transport is by airplane, automobile, or train, climate-controlled cabins rather than cargo-hold areas (when size permits) are preferred. "Air-ride" suspension trucks are also preferred. Sea travel is seldom used except for large and heavy items. If sea travel is chosen, crates should be stored in cargo hold instead of on deck. Hand carrying is suitable only for small items.

Couriers are recommended, especially for sensitive or fragile materials, extremely valuable items, items that could be misplaced (a small or single case object), items whose installation requires special procedures, or items that do not travel framed. In addition, these items will require arrangements for installation either by a conservator or experienced staff courier from the borrowing institution. Couriers should have knowledge of the packing methods, be able to monitor the items during transitional stages of the trip (holding areas, etc.), and have the authority to make decisions en route should circumstances dictate. Ideally, institutions should avoid shipping and transporting unaccompanied items.

When a courier is not possible, it is essential to pack and insulate well and to choose an experienced specialized handler and a secure route of travel. The staff on the receiving end should be informed of the anticipated arrival. Insurance for the item (in the event of damage or loss) should be considered and the financial responsibility of each party along each step of the trip clearly defined.

1.7.6 Environment during transit

Ideally, the temperature and relative humidity in the preparation, packing, and crating areas will be similar to storage or display conditions to reduce expansion and contraction within the item. Those responsible need to be alert to differing micro-environments within the crating or preparation areas that can adversely affect photographic materials.

Consistent environmental levels should be kept at all the stops along the way as much as possible, including storage and holding areas, warehouses, and within the airplane or truck. Severson (1986, 40) notes that temperatures and relative humidity levels can change rapidly during transit. An airplane baggage compartment may get as cold as -40°F (-40°C), while the interior of a truck can reach as high as 120°F (48.5°C). Richard, Mecklenburg, and Merrill (1991, section 2) recommend temperature-controlled trucks or cargo trains and relative humidity-controlled cases to minimize the potential hazards to materials.

Transportation during seasonal extremes of temperature and weather (e.g. winter and summer) may require more elaborate protective measures than transportation during times of less extreme temperatures and weather conditions. During wintertime travel protection for relative humidity control can be insured with additional case insulation. The receiving venue's climatic differences and potential climatic changes along the route taken there should be considered during packing, crating, and transport (Richard et al. 1991, section 2). Rainfalls and regional relative humidity variances can occur suddenly (Severson 1986, 40).

1.8 STANDARDS ORGANIZATIONS

1.8.1 Contact Information

American National Standards Institute (ANSI)
1819 L Street, NW, 6th floor
Washington, D.C. 20036 USA
202-293-8020 phone; 202-293-9287 facsimile OR
11 West 42nd Street, 13 floor,
New York, N.Y. 10036 USA
212-642-4900 phone; 212-398-0023 facsimile
ansionline@ansi.org
http://www.ansi.org

American Society for Testing Materials (ASTM)
100 Bar Harbor Drive
West Conshohocken, PA. 19428 USA
610-832-9585 phone; 610-832-9555 facsimile
service@localastm.org
http://www.astm.org

British Standard Institution (BSI)
389 Chiswick High Road
London W4 4AL United Kingdom
+44-20-8996-9000 phone; +44-20-8996-7400 facsimile
info@bsi-global.com
http://www.bsi-global.com

Deutsches Institut für Normung (DIN)
Burggrafenstrasse 6
D-10787 Berlin Germany/Deutschland
+49-30-26-01-0 phone; +49-30-26-01-12-31 facsimile
postmaster@din.de
http://www.din.de

International Organization for Standardization (ISO)
1, rue de Varembé
Case postale 56
CH-1211 Genève 20 Switzerland/Suisse
+41-22-749-01-11 phone; +41-22-733-34-30 facsimile
central@iso.ch
http://www.iso.ch

National Information Standards Organization (NISO)
4733 Bethesda Avenue
Suite 300
Bethesda, MD. 20814 USA
301-654-2512 phone; 301-654-1721 facsimile
http://www.niso.org

1.9 APPENDIX

1.9.1 Naming of polymers

Every effort has been made by the compiler to be accurate with names of materials. However, materials are often known by their local, generic, proprietary, or non-IUPAC (International Union of Physical and Applied Chemists) names, that vary from place to place. Therefore, this short glossary of some polymer terms used in the text is provided.

poly (actylaic) [polyacrylics]
IUPAC name: poly [1-alkoxycarbonyl) ethylene]
proprietary names: Rhoplex (co-polymer of poly [1-ethoxycarbonyl) ethylene] and poly [1-methoxycarbonyl)-1-methylethylene]

poly (carbonate)
IUPAC name: poly (oxycarbonyloxy-1,4,-phenylethylene)
proprietary names: Apec, Calibre, FR-PC, Iupilon, Lexan, Panlite, Sinvet

poly (ethylene) [poly (olefin)]
IUPAC name: poly (ethylene)
proprietary names: Aquathene, Bapolene, Ethafoam, Ferrene, Flexomer, Fortiflex, Polyplank, Sentinel, Tyvek, Unival, Volara, Zemid

poly (ethylene terephthalate) [polyester]
IUPAC name: poly (oxethyleneoxyterephthaloyl)
proprietary names: DuPont's Mylar® Type D, Melinex™ 516

poly (methyl methacrylate) [PMMA]
IUPAC name: poly [1-methoxycarbonyl)-1-methylethylene] (Conservators mainly use atactic form, although it also comes in isotactic and syndiotactic forms.)
proprietary names: Acrylite, Acryrex, Cyrolite, Lucite, Oroglas, Perspex, Plexiglas™

poly (propylene) [poly (olefins)]-
IUPAC name: poly (propylene) (isotactic); poly (propylene) (syndiotactic)
proprietary names: Adpro, Arpak, Arpro, Cefor, Eltex P, Escalloy, Escorene WPP, Hostalen PP, Propak, , Tyvek

poly (styrene)
IUPAC name: poly (1-phenylethylene)
proprietary names: Dylene, Ferroflo, Ladene, Replay, Styrofoam, Styron, Styropor, Valtra

poly (vinyl acetate) [PVA, PVAc] [see also poly (vinyl alcohol)]
IUPAC name: poly (1-acetoxyethylene)
proprietary names (emulsion): Duratite White Glue (DAP), Elmer's® Glue-All (Borden), Elvace 675CX, 1874 and 40-704, Gelva® (Solutia), Jade 403 and 711, Polymer Tempera (Bordon), Rivit Glue, Resin W, Vinavyl
proprietary names (resin): PVA-AYAA, PVA-AYAB, PVA-AYAF, PVA-AYAT, etc. (Union Carbide)

poly (vinyl alcohol) [PVA, PVOH] [see also poly (vinyl acetate)]
IUPAC name: poly (1-hydroxyethylene)
proprietary names: Elvanol® (DuPont), Galvatol® (Solutia), Gohsenol (Nippon Synthetic Chemicals), Lemonl (Borden), Mowiol (Hoechst), Polyviol (Wacker Chemie)

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Compiler's Note: The reference list consists primarily of printed articles and books. Information was becoming available via World Wide Web (www) access at the time of publication. Readers are encouraged to consult web sources for current information.

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Photographic Materials Conservation Catalog -- Chapter 2

Cased photographs

Including daguerreotypes, ambrotypes and tintypes

First edition, September 1998

The *Photographic Materials Conservation Catalog* is a publication of the Photographic Materials Group of the American Institute for Conservation of Historic and Artistic Works.

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2.1 PURPOSE

2.1.1 To stabilize the object -- physically and chemically.
2.1.2 To reintegrate the original case or package to best represent the original appearance of the object.
2.1.3 To provide preventive care during storage.
2.1.4 To consider traditional and current methods of removing tarnish from daguerreotype plates and other cosmetic treatments.

2.2 CASES AND OTHER HOUSING FORMATS

2.2.1 TYPES

2.2.1.1 Hinged case (commonly found on American and British plates)

The case is a multiple component structure which works to protect the photographic plate from physical damage and from the environment. Original cases also provide an appropriate aesthetic setting for the image.

The plate is contained in a package consisting of several layers. The plate, together with a metal mat and a cover glass, may be bound together with an adhered paper strip.

The metal mat is sheet brass. It is stamped (or molded) with a decorative pattern and may be etched to give an overall surface texture. Mats may be gilded and are usually coated with a colored varnish (shellac tinted with a variety of natural colorants). A mat provides a decorative setting for the image and keeps the cover glass, if present, away from the image surface. Note that while it may be possible to date brass mats of the 1840-1865 period on the basis of their thickness and decorative finish, this does not necessarily relate to the image date since mats may have been interchanged.

The preserver is a flexible strip of a copper alloy foil that folds around the glass/mat/plate package. The use of preservers on daguerreotypes began later in the 1840s, possibly 1847. They are usually stamped with a decorative pattern and serve a decorative purpose as well as protecting the paper binding, if this is present. Most importantly, the preserver *preserves* the daguerreotype image from tarnishing by preventing air ingress; it does this by pressing the package components together, most effectively when the package is pressed into the case. (See notes on the retainer also.)

Occasionally, no preserver was used; in such instances, the sealing tape is adhered to the edge of the cover glass but does not extend onto the front surface. This is more often seen in British cases than in American ones, although early American cases often lack the preserver.

The case is composed of two halves, a cover and a tray, that are hinged together. It may be covered with embossed or plain leather, molded paper or papier-mâché, textile (including velvet), lacquer/mother-of-pearl, or even more exotic materials. Leather-covered cases frequently show gilt tooling. The covering materials are adhered to the wooden base. Hinges may be of brass, attached to the trays with small brass nails. The hinge can also be created by extensions of the leather, textile or paper that covers the tray. When the hinge is contiguous with the covering material, there may also be an interior hinge to reinforce the exterior one.

The tray has a velvet-covered cardboard retainer around its perimeter. The retainer presses the components of the package together inside the cavity of the tray and acts to seal the package interior from air infiltration. The case cover holds a cushion -- a convex cotton pad covered with velvet or satin. The cushion reduces the volume of potentially harmful air inside the closed case and provides some protection to the cover glass from breakage. The case often has one or two brass hook-and-eyelet clasps attached on the exterior right edge to secure it closed.

The "Union case" is an American variation made with an early thermoplastic material composed of shellac, cellulosic fibres and pigments; this material was molded to make cases with detailed decorative motifs and representational scenes. Introduced in 1853, they usually have brass hinges and often have an integrated spring clasp rather than hook-and eyelet clasps.

Occasionally, two or more photographs are contained in the same case.

Not shown in the illustration (see next page), but frequently encountered in both daguerreotype and ambrotype packages, is the paper sealing tape adhered to the perimeter of these package elements which binds them together.

Ambrotype cases may differ somewhat from daguerreotype cases. If the ambrotype has not been painted with a pigmented lacquer on the plate verso, a dark-colored paper, textile or glass layer will be included behind the image plate. The cover glass may not be present in ambrotypes where the collodion image layer faces the interior (this having been done to correct lateral reversal of the image). In such instances, the metal mat and the preserver are adjacent to each another.

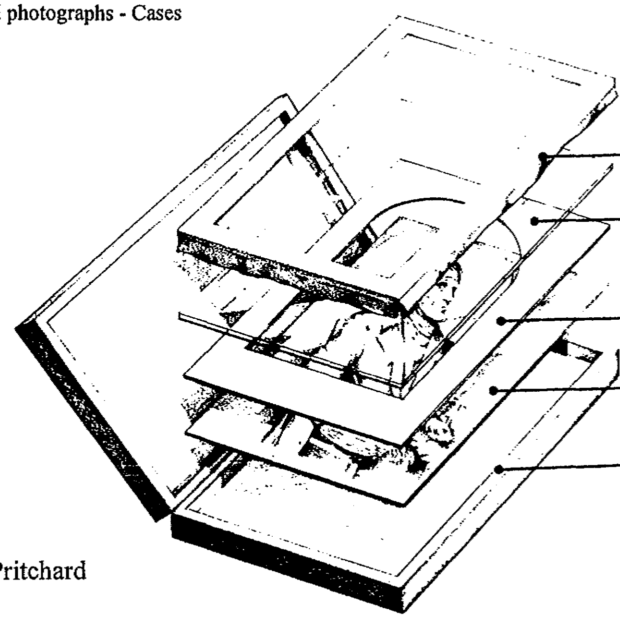


illustration: T. Pritchard

2.2.1.2 Passe-partout (European daguerreotypes, stereographs)

Daguerreotypes originating elsewhere than Britain and North America, as well as stereo-daguerreotypes, may be found packaged in this format. It consists of glass and paper elements with a cardboard backing. (See illustration below.)

Passe-partout with paper mat: The mat is usually a heavy wove paper with drawn or printed decoration. The mat aperture is most often square or octagonal in shape. The cover glass is fixed over the paper mat with a colored paper binding tape adhered around the package perimeter. (Some early American daguerreotypes, especially mourning portraits, incorporate gold-painted paper mats.)

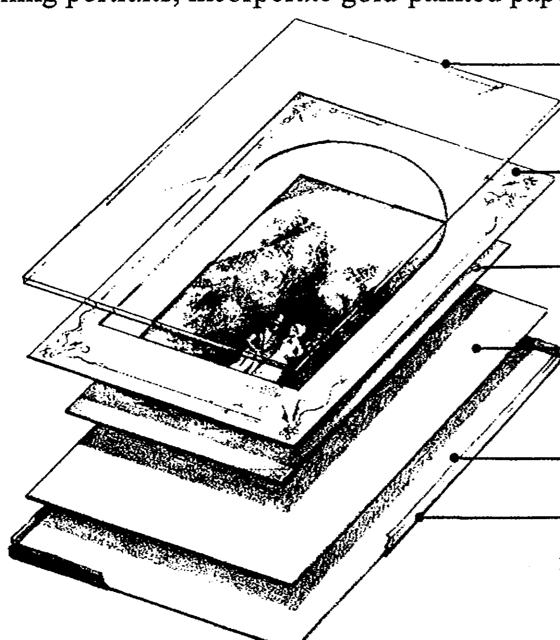


illustration: T. Pritchard

Passe-partout with reverse-painted cover glass: The earliest examples of this format are quite simple. Later examples include simple decorative lines, elaborate transfer designs or elaborate geometric patterns and decorative painting techniques (for example, tortoise shell patterns). When examined on the verso surface, these reverse-painted glass plates often have a matte-texture paint layer applied over the decorative paint, possibly as a protective layer.

Both types of passe-partout housings were eventually made commercially and could be purchased by the daguerreotypist. An open flap on the cardboard backing allowed the processed image plate to be placed in position under the aperture and fixed with several strips of adhered paper. The flap was then closed with more paper strips or with a paper sheet adhered over the whole package verso.

Paper binding tape was adhered to the package periphery. It may be colored or decorated to aesthetically integrate with the rest of the package design. (For instance, coated paper or marbled paper may be used as binding tape.) The cardboard backing of the package is usually covered with a colored paper sheet, and inscriptions and labels are often found here.

2.2.1.3 Frames

American, British and European daguerreotypes, ambrotypes and tintypes may be found in wooden, thermoplastic composite or papier-mâché frames. The plates will be contained in the same kind of plate packages that would otherwise be presented in a case or passe-partout. The frame may either be original or a later addition.

2.2.1.4 Paper housings

Small tintypes are sometimes mounted inside paper mats whose dimensions approximate the carte-de-visite format. These mats consist of a backing sheet onto which the plate is directly adhered, covered by an aperture overmat. The overmats were often decorated with embossed or printed motifs and with the photographer's identification. The top sheet is often adhered to the bottom sheet and to the concealed perimeter of the plate surface.

2.2.2 CONDITION

The leather, cloth or paper case hinges are often the weakest component in a hinged case. It is not unusual to encounter cases with the hinges either partially torn or with the trays completely detached from one another. Sometimes the cover will be missing. Hinges will often have been reinforced or replaced, often with poor-quality or inappropriate materials.

2.2.2.1 Leather and paper case coverings

Case coverings are frequently torn or have lost small sections; separation from the wooden base may have occurred. The exterior surface, particularly the raised portions of any pressed pattern, may be abraded, resulting in the loss of color and finish. Leather, particularly leather hinges, may be brittle. Gilt tooled or bronze painted decoration on the case exterior and interior may be soiled or abraded. A variety of surface coatings, especially waxes and oils, may have accumulated during a long history of cosmetic treatments.

2.2.2.2 Paper tape and mats

While goldbeater's skin was occasionally used to seal the edge of plate packages, sealing tape was most often made from strips of paper that had a thin layer of water-soluble adhesive applied to one side. Early daguerreotypists used strips of writing paper, but as the craft became an industry, rolls of paper tape prepared specifically for this purpose became available for purchase. The preservation state of the sealing tape depends on the quality of the paper used, the type of adhesive and the amount of mechanical wear that the seal has received in handling. Tapes might have been split open to examine the package interior and then inexpertly resealed.

Plates inside passe-partout packages were fixed with strips of gummed paper tape adhered to the verso surface of the paper mat or reverse-painted cover glass; these attachments are often found to have desiccated and released. Plates in this housing format frequently slip inside the package.

The paper mats of the passe-partout packages may be light damaged or may show adhesive stains. These packages may have been opened once or several times over the years to examine the plate; they will show evidence of more or less expert resealing. Several layers of backing paper, some of them fragmentary, may have accumulated on the package.

The paper mats applied to small tintypes may show staining and mechanical damage. Adhesives holding the plate to the paper may have desiccated and failed, leaving the tintype plate loose between the paper layers. The adhesives used may have initiated rusting of the iron support.

2.2.2.3 Glass

Glass used for both glazing and support materials for cased photographic images was usually commercially available pane glass. There were some companies that sold "photographic" glass destined for use as supports for photographic plates. This glass was free of physical flaws and was relatively colorless, but did not have superior durability or corrosion resistance.

All glass is subject to physical breakage. Broken cover glass on cased photographs may cause immediate physical damage to the image underneath. In addition, it may lead to chemical deterioration of the image in the localized area under the breakage by allowing the direct ingress of air; this is particularly common with daguerreotypes with cracked cover glasses.

Some glass formulations are chemically unstable due to a high flux content, especially those with a high ratio of sodium flux in proportion to the alkaline earth flux (calcium and magnesium oxide). Note that glass with a high sodium content produces a yellow-orange fluorescence under UV illumination, whereas glass with a higher alkaline earth content tends to produce orange-magenta fluorescence. Glass corrosion is caused by inherent instability linked to unfavorable environmental conditions.

Glass corrosion, leading to the accumulation of alkaline materials and silicates on the surface of the glass, is a major cause of deterioration in cased photographs. Unfortunately, the design of the cased photograph package encourages the type of corrosion in cover glass called "static weathering." In this process, the inner surface of the cover glass is exposed to a small enclosed air volume; this air is subject to transient periods of high or cycling relative humidity.

The glass used in photographic packages should be checked regularly for signs of weathering corrosion. It may be easier to detect corrosion films by examining the glass by specular reflection. Look for:

- early signs -- a faint surface haze or clouding;
- more advanced states of "weeping" glass, including the presence of tiny droplets that lend a "greasy" or "soapy" feel to the surface; these are primarily amorphous sodium silicates (water glass) and have a high pH -- in the range of 10-14 (the presence of alkaline corrosion products may be detected by burnishing a pH indicator strip on to the affected surface);
- needle-like crystals and incrustations on the inner surface of the glass -- they may also have spalled off, leaving the crystals on the surface of the photograph below;

- blister-like crystals that appear to have a small darker-colored core;
- mold-like masses on the surface of the daguerreotype plate below, sometimes obviously associated with a spalled-off crystal corrosion product from the cover glass above; these have a "bead-and-thread" morphology reminiscent of *Candida* spp. but are entirely inorganic.

(Refer to *Barger; Smith; White (1989)* for more information on cover glass deterioration.)

2.2.2.4 Wood trays

The wooden structure of the case may be found in poor condition, with the front or back surfaces warped, joints broken, structural members split, and glue desiccated and released. Side members are often missing altogether. The paper or leather coverings may have begun to lift from the underlying wood structure.

2.2.2.5 Composite thermoplastic

Union cases may show warpage, "blanched" or roughened surfaces, cracks or other physical damage (often located at the insertion and attachment points of the brass hinges). Storage for extended periods at higher temperatures or excessive light exposure both seem to be damaging. Prior cleaning and cosmetic treatments may include the application of water, detergents, solvents, petroleum jelly, furniture polish and shoe polish.

2.2.2.6 Brass preservers, mats, hinges and clasps

The most common deterioration observed on the varnished brass mats are the small randomly distributed spots of brown, black or green copper corrosion products that appear to be under the varnish layer but which may effloresce. Less common is the observation of large fields of even discoloration over sections of a mat. The occurrence of local copper corrosion has been linked to contact with the alkaline products of glass corrosion. Tiny holes in the varnish film and exposure to elevated humidity have also been cited as causes for brass corrosion on mats and preservers.

Preservers, made from a flexible copper alloy foil, are subject to mechanical stresses and fatigue due to the action of folding and unfolding. The most common deterioration of these components is mechanical breakage, usually occurring at one or two of the corners.

Hook-and-eyelet clasps are sometimes found to have been broken; hooks are sometimes missing altogether.

2.2.2.7 Textile covers for cushions and retainers

The most common deterioration seen on velvet coverings is the accumulation of lint, dust and dried accretions. Cushions may be damaged by insects. Retainer coverings may be worn, abraded and compressed; they may no longer provide adequate pressure along the package edge. Silk cushion coverings are sometimes found in a fragile and worn state. While the dyes used on these textiles may be quite sensitive to light, light-induced fading is less frequently encountered because these components have been protected inside the closed cases.

2.2.3 TREATMENT

In the following section, it is assumed that all treatments will be carried out by qualified conservators familiar with the materials and characteristics of the objects they are treating. No treatment indications given here can be considered safe for any object without suitable spot testing, careful observations and skilled, judicious application.

Removing the package from a case: Cases usually have step joints, not mitred joints, and these tend to be weak. If the package is sound (preserver and/or sealing tape intact) it may be possible to use a small suction cup to gently lift the package out of the case. If it is necessary to use a micro-spatula, carefully work the plate out from the top or bottom end. A microspatula with a small section of the tip bent in at 90° may be helpful in lifting the package out of the tray. Keep a firm grip on the edges of the case to counteract the leverage of the micro-spatula. Do not force the package out. It may be impossible to safely remove the package; if this seems to be the case, stop and reassess the procedure.

Disassembling the package: If an object is not in need of preservation or restoration treatment, it should probably not be disassembled. This is particularly true for those few cased photographs that appear to have their original seals present and intact; there are so few objects in this state that conservators must be wary of obliterating potentially valuable historical evidence.

If disassembly is to be done, keep the following points in mind:

- make a detailed record of the configuration of the package as disassembly proceeds;
- make sure you can reassemble the components in the orientation in which you found them;
- minimize the stress on the preserver's flaps and corners by working in stages and

using a solid vertical support against the side surfaces of the preserver;

- minimize the risk of damaging the plate by carefully removing the opened preserver from the package components, rather than levering the package components out of the preserver; small clips might be used to keep the plate and mat from sliding against one another during preliminary steps;
- sealing/binding tapes should be removed intact so that they might be reused to reseal the package;
- identify and archive, if possible, any glass or paper components that are permanently removed from the package;
- wear clean gloves when handling daguerreotype, ambrotype or tintype plates; latex examination gloves provide better touch sensitivity than cotton gloves but care must be taken to ensure that talc traces are not present on the glove exterior;
- never lay a daguerreotype plate face down;
- after examination or treatment, reseal the package (see Section 2.2.3.10 on resealing) and replace the preserver; ensure that the treatment has not increased the size of the package, producing new stress on the joints of the case.

2.2.3.1 Leather

Leather may be gently cleaned with small swabs dampened with a ethanol/water (1/9) mixture. (Some leather colorants may be soluble in alcohol.)

Areas of lifted leather may be reattached to the wood structure with starch paste, polyvinyl acetate (PVA) emulsion adhesive or with methylcellulose paste (3-4% w/v). Where judged appropriate, skinned and abraded areas may be consolidated with diluted PVA emulsion or methylcellulose paste (approximately 1% w/v) and tinted with acrylic paint . Coatings such as microcrystalline wax or diluted PVA emulsion may be used to modify surface gloss.

Losses can be compensated with paper infills, either from pulp or from appropriately textured sheets adhered with a diluted PVA emulsion or methylcellulose paste. Paper pulp or tissue can be manipulated and molded while damp to replicate relief elements of the case surface. These can be pre-tinted or tinted with watercolor after application. Watercolor mixed with diluted PVA emulsion may be used to modify gloss. Alternatively, microcrystalline wax or untinted PVA emulsion can be applied over the watercolor to alter the infill gloss.

After all other structural and cosmetic treatments have been completed, some conservators may sparingly apply microcrystalline wax that is buffed to produce an even surface finish.

For repair of hinges, see Section 2.2.3.8 below.

2.2.3.2 Paper

Losses to the paper covering on the exterior of a case can be filled with paper sheets or pulp in the same way as losses in leather coverings, as described in the section above.

Paper mats inside passe-partout daguerreotype packages can be treated as other paper objects, including dry cleaning, washing, bleaching, repairing, infilling, lining and flattening, as required and if possible. Deacidification treatments which leave calcium or magnesium residues should be avoided so as not to introduce potentially harmful materials into the sealed package.

Paper mats for tintypes, if they can be safely separated from the plate, can be treated similarly using the full gamut of paper conservation techniques.

Decorative paper strips and paper frames used as sealing tapes on passe-partout packages or any damaged original sealing tape can also be treated. Often these tapes will be found to have been split open and inadequately repaired; sometimes later additions of sealing tape will have been applied directly over original tapes. Conventional paper conservation treatments can be used to remove, restore and reuse this original material. Lining damaged original paper strips onto a thin Japanese paper or onto lens tissue with dilute starch paste will allow these components to be reused, either alone or over a new sealing tape.

For repair of hinges, see Section 2.2.3.8 below. For resealing, see Section 2.2.3.10 below.

2.2.3.3 Thermoplastic composite material (Union case)

Little has been reported about cleaning or repair treatments for this material. *B. L. Smith (1994)*, in a study of these cases, has pointed out some potential problems with aqueous cleaning treatments. She recommends reliance on dry cleaning methods, including brushing, vacuuming and mechanical excavation.

Smith cites a successful use of 10% Acryloid B-72 in toluene to repair breakage. Losses have been successfully filled with a two-part epoxy putty, Araldite, which can be toned with acrylic emulsion or acrylic resin paints. Smith also cites a collector using Arcon 140 epoxy tinted with oil paint to fill losses.

2.2.3.4 Glass

While handling glass objects, always ensure that they are well supported. Use a padded board as a work surface. This can be made by covering a piece of heavy cardboard with cotton textile and many layers of lens tissue. The lens tissue can be removed one layer at a time as it gets soiled.

Noncorroded glass: Undeteriorated but dirty cover glass may be cleaned and reused. (Note that it may be impossible to distinguish dirt from deterioration with certainty.) Begin by brushing the glass surface with a long-haired soft brush. Always brush from the centre of the plate outward. Clean the glass with wads of cotton wool or large swabs. Use an ethanol/water mixture or an acetic acid solution for cleaning glass. Ethanol improves the efficiency of cleaning and aids in the evaporation of the water. Once the glass is clean, it should be wiped with lens tissue. To check cleaning, breathe on the plate and watch the evaporation. If the vapor evaporates evenly, the plate is clean. Glass cleaning solutions containing ammonium hydroxide should not be allowed to contact the surface of an ambrotype.

Corroded glass: Some conservators and conservation scientists advise that cover glass showing signs of corrosion should always be removed and replaced with new glass. Deteriorating glass should not be cleaned and reused as the cleaned, unstable glass will then enter into a new and rapid phase of deterioration.

Others recommend that deteriorated cover glass be retained in place, but only if the object is to be stored in a humidity-controlled area (40-55% RH) and will be regularly monitored. In this case aqueous cleaning should not be done, only dry cleaning, in order to avoid starting a new, rapid corrosion cycle. (Contributor Susan Barger notes that cleaning with vinegar -- dilute acetic acid -- followed by polishing is an acceptable practice for corroded glass that is to be retained.) If the object is to return to an uncontrolled environment or if regular monitoring is unlikely, the deteriorated original glass should be removed and replaced with new glass.

It may be possible to retain a deteriorating cover glass while separating it from the plate and mat below. This can be done by introducing a transparent barrier such as Mylar or new glass. Note that this might accelerate glass corrosion at the interface.

Reverse-painted cover glasses may show paint losses and cleavage, but no glass deterioration; in such cases, the paint can be consolidated and inpainted with acrylic emulsion paints or acrylic resin paints. When reverse-painted cover glass shows evidence of glass deterioration, a copy may be produced on a new glass as a replacement using the paints noted above; spray application of diluted paints using a self-adhesive mask to protect the unpainted aperture produces the most satisfactory result. Where copying or replacement is impossible or undesirable, a transparent barrier may be placed under the deteriorating original cover glass.

It should be remembered that even the best quality of replacement glass may itself

It should be remembered that even the best quality of replacement glass may itself show signs of deterioration ten to twenty years after its installation. This is due to the unfavorable configuration of having sheet glass adjacent to a small enclosed airspace which is the unavoidable geometry of the cased photograph package. Inspection programs to detect glass deterioration are necessary even for objects that have new cover glass. Also, since replacement is not an absolute remedy to the problem, some conservators argue for intermediate or hybrid approaches which maintain the original components together.

If a replacement is to be made, most ordinary modern picture framing glass can be used as long as it is free of flaws and color cast. The edges of newly cut glass should be sanded (use wet/dry sandpaper or a whetstone); this removes the sharp edges that can cut through the sealing tape and provides a better tooth for adherence.

Specialty glass, such as antireflection glass, is probably an unnecessary expense because it is not significantly more durable than ordinary picture framing glass. Also, cased photographs require carefully controlled display illumination, so there is little advantage to be gained from antireflection glass. Some antireflection glass is colorless (for example, Tru Vue - Premium Clear). This might be considered when the slight greenish cast often found in common window glass adversely effects the appearance of the photograph. Polymer glazing materials, such as Plexiglas, should be avoided. These scratch easily and do not provide a barrier to corrosive gases. However, note that some contemporary daguerreotypists use acrylic glazing, rather than glass, in their plate housings.

All collections of cased photographs should be monitored regularly for glass deterioration.

When the support glass of an ambrotype corrodes, there is very little treatment that can be done to alleviate the damage caused by the corrosion. Ensure that the object is maintained in a stable environment with minimal humidity fluctuation.

2.2.3.5 Wood

Broken or detached wooden case components can be repaired using hide glue or PVA emulsion. Repaired joints must be clamped during drying; small frame clamps or elastic bandages, in addition to a variety of small spring clamps, will be useful for this purpose. Missing wooden members can be replaced with balsa wood or with 8-ply matboard, trimmed to fit precisely and covered with paper and finished to match the original case materials. Joints can be reinforced with paper reinforcements applied with PVA emulsion adhesive or methylcellulose paste.

Trays that have opened corner joints and that cannot be closed around a package that is slightly too large may be modified by adding matboard or balsa shims at the opened joints. These can be covered and finished as noted above.

2.2.3.6 Brass

Surface dirt on brass components may be reduced with dry or damp cotton swabs. It may be possible to wash these components in water containing a surfactant to remove heavier soil accumulation; they must be rinsed and carefully dried after water cleaning to avoid initiating or accelerating corrosion. Mats and preservers were usually varnished with tinted shellac; these coatings may be soluble in alcohol or other organic solvents.

Corrosion products that project above the surface of the metal as brittle blisters may be reduced mechanically, using sharpened wooden sticks (preferably hardwood) or pointed scalpel blades or other micro-tools. It may be advisable to coat areas treated in this way; consider acrylic resins (Acryloid B-72; B-67; B-48N) or Incralac, which contains benzotriazole (BTA) -- a corrosion inhibitor.

Inpainting may be done with "metallic" pencils; acrylic paints; gouache paints; acrylic resin Acryloid B-72 or methylcellulose mixed with bronze powders; or acrylic emulsions Rhoplex N580/AC-33 (1/1) mixed with Mica Pigments. An appropriate isolating layer should be used beneath all inpainting.

Where a burr on the verso edge of the mat aperture has produced scratches on a daguerreotype plate surface, further damage can be avoided by several measures:

- the sharp edge may be dulled or rolled forward with a stainless steel burnisher;
- a sheet of spacer material can be custom cut and introduced underneath the mat; use one of the thicker nonwoven polyester web materials;
- several thin spray applications of Acryloid B-72 to the sharp edges will even out the surface.

Broken preservers may be repaired with a viscous Acryloid B-72 formulation (HMG adhesive) and brass foil. The exterior surface of the broken corner is temporarily taped together, then a small L-shaped piece of brass foil is pressed into place on the interior side, molding it into the three-dimensional conformation of the stamped design with a bone folder or other appropriate shaping tool. The reinforcing foil is then removed, coated with the viscous adhesive on the contact surface, pressed into place and allowed to dry. This process can be repeated to provide further reinforcement.

2.2.3.7 Textile

The cushions and retainer strips inside the case may be first cleaned by blowing loose dirt away with a rubber bulb blower or by using a Mini-Vac equipped with a plastic pipette attachment. More solidly adhered debris might be removed using a medium bristle brush. Water treatments are not advised.

Stained areas on the retainer may be successfully "overpainted" with pastel pencils.

Missing textile cushions and retainers can be reconstructed using acrylic or cotton velvet, high-quality 2-ply matboard and cotton batting. Such reconstructions should be carried out with the collaboration of a knowledgeable curator or custodian.

2.2.3.8 Repairing broken hinges

If the trays are completely detached from each other, begin by lifting the original covering material along the interior and exterior hinge edges. Whether the case is covered with leather, cloth or paper, the material is usually very thin and easily torn through. It is important to work slowly to control the lifting. Dampening the material frequently with an ethanol/water (1/1) mixture may help prevent delamination. Once the hinges are lifted, introduce the repair material.

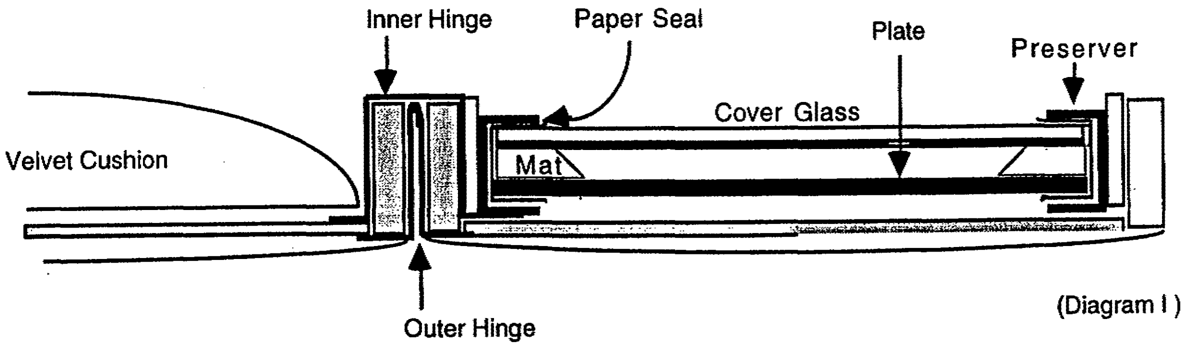
In choosing the repair material, consider strength and flexibility requirements, and compatibility with the original material. Choices for repair materials include:

- bookbinders' repair vellum sanded to tissue thickness;
- lightweight Japanese paper or 40 gsm Silversafe paper (cut with machine direction perpendicular to strip);
- thin nonwoven polyester web material, such as Cerex or Reemay;
- if the broken hinge is a simple leather strip, consider using a strip of new, properly toned leather as replacement.

The most common repair adhesives are PVA emulsion (usually diluted), methylcellulose and starch paste. The choice of adhesive depends on flexibility requirements and on the repair material chosen.

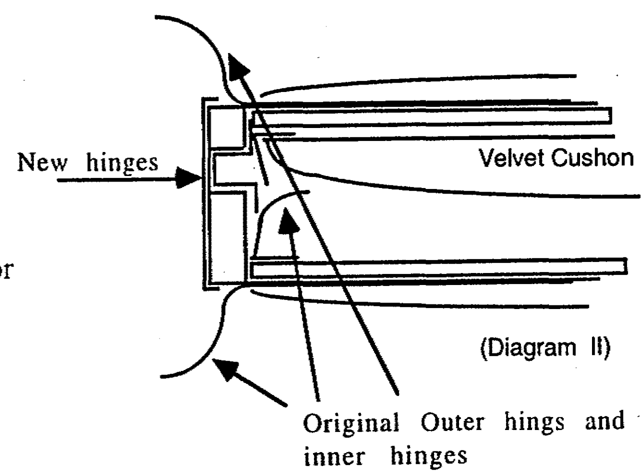
The repair material is cut in strips of appropriate width and adhered to the wooden surfaces. The repair strip is then covered with the flaps of the original covering. Weight the repair after readhering the flaps.

If both inner and outer hinges are to be repaired, start by repairing the outside hinge, then repeat this procedure for the interior hinge.



(Diagram I)

Illustrations: Toshiaki Koseki



(Diagram II)

Prepare infills as outlined in Section 2.2.3.1 and tint the exposed areas of the repair with watercolor, watercolor in dilute PVA emulsion, acrylic emulsion paint (Liquitex gloss medium) or tinted wax.

2.2.3.9 Repackaging plates

For daguerreotypes, two distinct approaches to repackaging exist. In one approach, the sealed daguerreotype package contains no hygroscopic material, thus avoiding the presence of a reservoir of moisture inside the package that could drive the various processes of metal corrosion. This practice reflects the original format of cased daguerreotypes where no paper products, except the sealing tape, were included in the package. The other approach is to intentionally include a quantity of high-quality unbuffered matboard inside the sealed package (but not in direct contact with the daguerreotype image surface). This acts as a humidity buffer inside the package, helping to dampen relative humidity fluctuations inside the package. This practice reflects the original format of passe-partout packages, which contain substantial quantities of paper, cardboard and adhesives.

Whatever repackaging method is chosen, it is essential to ensure that all of the package components are well secured and will not slip or shift. Mechanical damage due to component slippage is a common phenomenon in cased photographs and avoiding future occurrences should be a major criterion in choosing a repackaging method.

2.2.3.9.1 Nonhygroscopic package

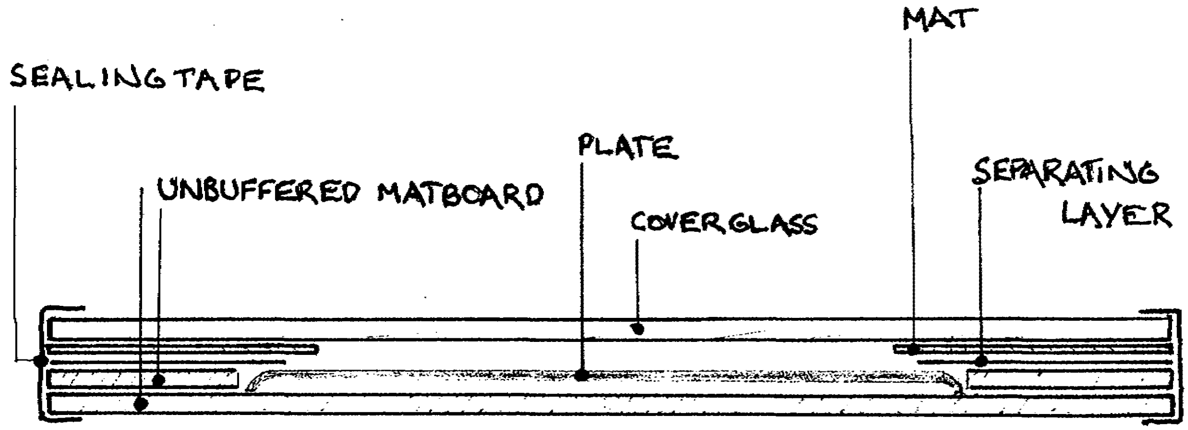
This method uses a moisture-resistant barrier on the back of the package and does not introduce any hygroscopic material inside the package. A 5 mil Mylar backing is cut to be slightly smaller than the plate. If a barrier is required to prevent abrasion of the plate surface (see Section 2.2.3.6), use a layer of a nonwoven polyester web material. The package is closed with a moisture-resistant sealing tape (see Section 2.2.3.10). This style of repackaging has the advantage of adding little or no extra thickness and allowing the plate verso to be seen without disassembling the package. Marvelseal, a nylon/aluminum/polyethylene laminate, has also been used as an impermeable backing, but it lacks the advantage of transparency. If the plate is much smaller than the package, this method is difficult to use.

2.2.3.9.2 Humidity-buffered package variant

Modify the package described above by including a rectangle of matboard cut to precisely fit between the verso of the daguerreotype plate and the Mylar. Use high-quality matboard that does not contain alkaline pH-buffering compounds and that has been conditioned to an appropriate moisture level. Use a matboard thickness that will not add significantly to the package thickness if the plate is to be returned to a case.

2.2.3.9.3 Matboard sink

This variant is most useful in the repackaging of passe-partout style packages and stereo-daguerreotype packages. A multilayer matboard structure is made that holds the plate in correct register, provides maximum support for all edges and for the plate verso surface, and provides a separation between delicate surfaces and the glazing material. Use rectangles of high-quality, unbuffered 2-, 4- and 8-ply matboard cut larger than the finished package size to create a sink cavity for the plate. Use a layer of a nonwoven polyester web material to provide separation between the plate and any original package components that may cause abrasion or scratches. Adhere these layers with 3M Double-sided Tape No. 415, starch paste adhesive, methylcellulose paste or PVA emulsion adhesive. It is essential to add only the minimum possible additional thickness to the package if it is to be returned to a case.



2.2.3.9.4 George Eastman House housing

The Conservation Department at the George Eastman House has developed an elegant structure for housing unpackaged daguerreotype plates that combines some features of both approaches outlined above. This housing was inspired by a unique metal and paper housing associated with the American daguerreotypist Robert Cornelius. A matboard sink mat is made with cavities for the daguerreotype and for the cover glass. (See drawing on next page.) The daguerreotype cavity is slightly deeper than the total thickness of the plate, including its bevelled edges. The cover glass cavity should be the same depth as the glass thickness. A 5-mil Mylar cradle holds the edge of the plate and prevents it from moving inside the slightly oversized cavity or from contacting the inner surface of the cover glass. The cradle is made from two sheets of Mylar. One is cut to the width of the plate and folded at the top and bottom edges to form a Z-shaped spacer or spring; the other is cut to the height of the plate and is folded to form "Z" springs at the sides of the plate. The ends of the Mylar sheets should be trimmed to fit precisely into the spaces of the cover glass cavity. Once the cradle, the daguerreotype plate and the glass are precisely fitted into the matboard sink structure, the glass is sealed to the top surface of the matboard with paper tape. This system can be adapted to include an original brass mat behind the cover glass. The finished package can be easily overmatted and framed for display.

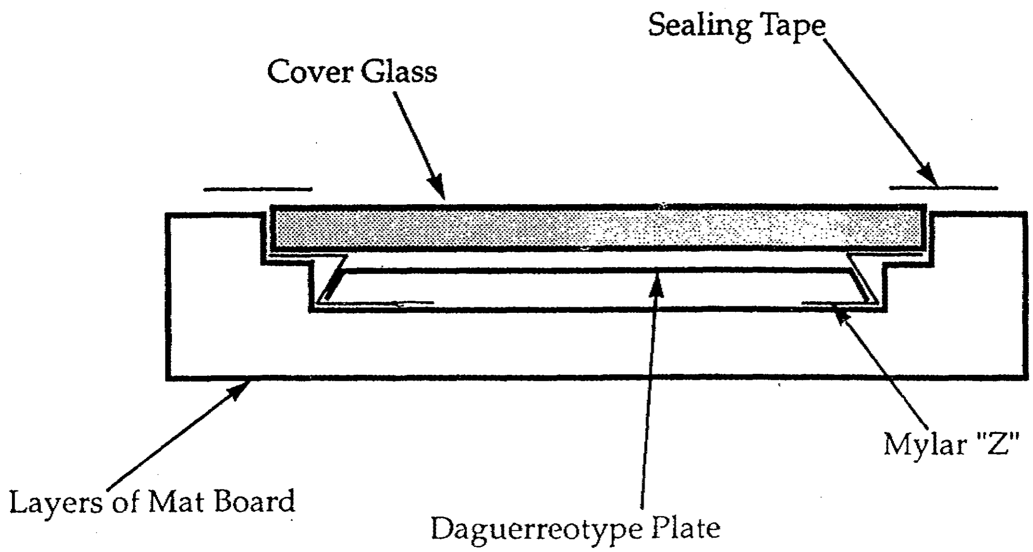


Illustration: GEH

2.2.3.10 Resealing

Reusing original tapes: This should be done when possible to preserve the original package components. It may be possible to change a deteriorated cover glass by releasing the tape from the front with minimal solvent application, removing the glass, fitting in the new glass and reactivating the original adhesive to secure the new glass. Damage on the original tape can be repaired using conventional methods. If original binding tapes must be removed and replaced with new materials, consider storing the removed tape fragments in the case tray, behind the package.

Self-adhesive tapes: Many conservators prefer pressure-sensitive tapes for sealing cased photographs because they are easier to handle than paper tapes made with wet adhesives and they do not introduce moisture into the sealed package. Paper tapes such as Filmoplast P-90, Filmoplast P-91 or Filmoplast T (textile carrier) have been commonly used to reseal cased photographs. Polyester-backed or Mylar-backed tapes provide some moisture barrier. Notable among these are the 3M Polyester Tape No. 850 (Silver), which is thin and flexible.

It may be preferable to isolate the edge of the daguerreotype plate from contact with the adhesive. This can be done by laying a thin strip of nonadhering material down the centre of the sealing tape. Use 3-mil Mylar, Hollytex, Japanese paper or a thin strip of the sealing tape itself, turned so that its nonadhesive surface contacts the plate edge. See application instructions under "Plain paper tapes" below.

Self-adhesive tapes can be used alone or be covered with the original paper sealing tape that has been removed and treated as described in Section 2.2.3.2. These auxiliary paper seals may be adhered with diluted PVA emulsion adhesive, methylcellulose paste or with a mixture of wheat starch paste/methylcellulose/PVA emulsion (3/3/1).

Plain paper tapes: Note that the use of aqueous adhesives may produce an unavoidable exposure of the package components to moisture. Consider using the alternatives described above.

Choose an appropriate paper. Examples are: Renaissance paper; 40 gsm Silversafe; a decorative paper tape, lined onto more stable or stronger paper if necessary. Paper tapes should be cut across the grain (machine direction perpendicular to the length of the strip) to give the maximum strength across the seal.

Choose an appropriate adhesive. Examples are: wheat or rice starch paste; PVA emulsion (undiluted); methylcellulose paste; mixtures of starch paste, methylcellulose and PVA emulsion. Starch pastes should be used stiff and be applied sparingly. (If there is any risk of the adhesive wicking between the package layers, the wet adhesive method should not be used or try using the non-adhesive strip technique described previously.)

Place one edge of the plate package on the pasted tape and walk the plate around it until the strip is adhered to the edges in a continuous band. A weak clamp applied (with a cushioning barrier) to one edge of the package may help. Trim the excess length away before laying down the last section of the strip; there should be a slight overlap of paper where the ends of the strip come together. Lightly rub the edges to set, taking care not to tear the paper. Pinch the corners so that they come together in a triangle that is perpendicular to the plate package. Cut the triangles with a pair of scissors at a 45-degree angle. Working around the plate, lift one edge of each corner and push the other edge underneath it. This will enable the corners to lay flat. Let the tape air dry for at least one hour before trimming or tinting.

Make the trimming cut with a very sharp scalpel, being careful not to scratch the glass. If the tape is to be tinted, apply the paint before removing the excess strip; the waste paper will act as a guard for the glass and allow the tinting medium to absorb into the cut edge of the tape. When the tape is dry, remove the excess strip.

2.3 DAGUERREOTYPE PLATES

2.3.1 PROCESS

Daguerreotypes are direct positive photographs on metal supports. The supports are copper plates clad with a polished layer of metallic silver. The image particles, which lie on the surface of the polished silver, constitute the image highlights; they are primarily composed of silver but may contain small amounts of gold and mercury. In highlight areas, the silver image particles scatter incident light and appear to be white, while in the shadow areas the polished silver reflects light like a mirror; when the plate is positioned to reflect a dark surface, the image appears as a positive. Image particle size and spacing are in the same order of magnitude as the wavelengths of light; this may result in the appearance of physical (noncolorant) colors in the image through diffraction effects, particularly in highlight (high particle density) areas.

Fine parallel polishing lines are typically observed on daguerreotype plates. They are generally horizontal across the image, since the plates were designed to be looked at using a light source positioned to the side, rather than above, the image. These marks should not be confused with damage.

During plate preparation, a silver electroplating step may have been employed; this will usually be signalled by the presence of a dull silver layer on the plate verso.

From 1842, daguerreotypes were routinely "gilded" -- treated with a solution of gold chloride. This procedure, which heightened the image contrast, also seems to have improved the resistance of the plate to tarnishing and hardened the image particles against physical disruption.

Daguerreotypes were sometimes hand-colored by the careful application of dry pigments mixed with gum arabic; colored areas may have transparent overcoats applied.

Most daguerreotype images are laterally reversed; some late daguerreotype cameras included a mirror system to correct the image reversal.

2.3.1.1 Daguerreotype plate size designations

Because of the approximate way in which the silvered plates were cut down by daguerreotypists to make smaller formats, the confusion between metric and imperial units, and the existence of at least two sets of standards, there are some discrepancies in the published dimensions of daguerreotype full plates and fractions. The regular

American "whole-plate" (or "full-plate" or "4/4") is 8½ x 6½ inches. The half-plate (6½ x 4¼), quarter-plate (4¼ x 3¼) and eighth-plate (3¼ x 2 1/8) sizes are simple divisions of the full plate. The sixth-plate (3¼ x 2¾), ninth-plate (2½ x 2) and sixteenth-plate (1 5/8 x 1 3/8) formats are not simple fractions. The sixth plate is the most common studio portrait format.

Another set of plate formats derives from the "Imperial" (or "Mammoth") plate that measures 14 x 11 inches. A 14½ x 16½ inch plate is also reported. Plates exist which are as large as 16 x 24 inches. Panorama format plates also exist. See references in *Buerger*, *Kempe* and *Rinhart (1975)* on these formats.

Note that plates may have been precut by the plate manufacturer, in which case they will often show the manufacturer's name and a plate grade as blind-stamps in one corner. (Higher grade numbers indicate thinner silver layers on the copper plate.) Alternatively, the daguerreotypist may have done the cutting. These plates usually lack the manufacturer's identification; they may be irregular in shape and may deviate from any standard dimensions.

2.3.1.2 Stereo-daguerreotypes

Stereographic images were sometimes made in multiple image (nonstereograph) cameras, then cut and realigned to create a stereographic effect. When removing these from a package for treatment, ensure that the plates can be unambiguously identified for return to the package in their proper orientation. A carefully recorded diagram of the relative spacings of the plates within the package should be included in the pretreatment documentation. The stereo effect may be checked by observing the image through a stereoviewer.

2.3.2 CONDITION

2.3.2.1 Metal plate

Daguerreotype plates are manufactured by the "Sheffield plate process" in which a thin layer of silver is fused to a copper ingot by heat then rolled to the desired plate thickness.

Exfoliation may occur; in this condition the topmost silver layer carrying the image particles separates from the underlying silver layer which remains bonded to the copper support.

All types of metal supports are subject to mechanical distortion from bending or other types of mechanical working. Mechanical distortion frequently results in damage to image layers.

All types of metal support materials used for photographs are subject to corrosion or degradation caused by the oxidation of the metal itself. In daguerreotypes, this may be seen as films, spots and blister-like growths on the plate surface.

The daguerreotype's silver surface is susceptible to tarnishing. Tarnish products, primarily silver oxides, may cover the entire plate or be concentrated at the edge of the mat window opening. Thin, evenly deposited tarnish films are characterized by a series of interference colors. The most brilliant series of colors occur where the tarnish layer is thinnest. Thicker, more uneven tarnish films appear pale grey or black, the color of bulk silver oxides.

The alkaline gels and silicate crystals formed by weathering corrosion on the inner surface of the cover glass may spall off onto the daguerreotype surface, where they can initiate various types of metal corrosion. One form of such corrosion are the mold-like masses previously noted in the discussion of cover glass corrosion (Section 2.2.2.3). *Barger; Smith; White (1989)* report deep dendritic fissures in the daguerreotype surface where these masses have grown. Other forms of corrosion on the plate surface may result from the transfer of glass corrosion products. These may show as variable-size grey spots on the plate that may be nucleated and may have associated accretions. Note that grey spots may also derive from splashes of mercury deposited on the plate during processing

Some daguerreotypes develop green-colored blister-like growths. These are due to copper corrosion formed at tiny holes in the silver layer of the plate. Bronze powder particles may produce similar corrosion products.

Various chemical cleaning treatments may have produced microscopic pitting of the silver surface. This may be manifested as a lowered overall image contrast or by the appearance of a white, cloudy "veil" over the image.

Daffner; Kushel; Messinger (1996) have noted a bright fluorescence on some daguerreotype plates under short-wave UV illumination (UVC; 200-280 nm.). The significance of these observations is not yet entirely clear, but the authors associate the fluorescence with previous chemical cleaning treatments, prolonged exposure to the environment, general mishandling and the presence of cyanide compounds.

2.3.2.2 Image layer

Daguerreotypes do not have a binder layer; instead, the image particles of the daguerreotype are formed directly on the surface of the daguerreotype plate. The daguerreotype surface has a micro-scale roughness due to the topography of the image particles.

2.3.2.3 Silver image

The image particles found on a daguerreotype plate are 0.1 μm to 50 μm in diameter (roughly 10 to 100 times larger than those found in other types of photographs). Daguerreotype image particles are primarily composed of metallic silver but may include small amounts of gold and mercury. Image particles are susceptible to mechanical abrasion.

Daguerreotype image particles are susceptible to oxidative corrosion, as described above for the silvered plate (Section 2.3.2.1).

Residues from thiourea cleaning may cause spots, or "measles," on daguerreotype surfaces. As the plate is repeatedly cleaned with cyanide- or thiourea-based chemical cleaning solutions, the image particles are reduced in size and their spacing increases, resulting in reduced image contrast. Residues from cyanide and thiourea cleaning also leave corrosive films on the entire plate surface.

The daguerreotype image does not fade due to light exposure.

2.3.2.4 Coatings

A variety of protective coatings were initially proposed for daguerreotypes before the introduction of gilding. These included varnishes of copal and other resins and glues. This was not widely practised, and coated plates are extremely rare. Some modern materials have been tested for use as protective coatings for daguerreotypes and are not recommended..

2.3.2.5 Paint/pigment components

To color the surfaces of daguerreotypes, pigments were ground into a fine powder with gum arabic and applied dry to the surface of the images. In one application method, the colorist breathed lightly over the area to warm and humidify the gum, thereby activating the adhesion of the powder to the plate. Colorants are sensitive to light, moisture and abrasion.

"Shell gold" (metal powder in oil or gum arabic solution) was used to highlight selected image areas, such as buttons and jewellery. A sharp tool may have been used to scratch into the image surface to create highlights and to reinforce or create image elements.

2.3.2.6 Photographing daguerreotypes

Reprography of daguerreotypes is complicated by the appearance of reflected images of the copy camera, copy photographer, etc., in the daguerreotype plate, as well as by misleading exposure readings from "through-the-lens" (TTL) camera light meters.

The plate should be oriented with the direction of the final polishing marks -- usually horizontal across the image -- parallel to the direction of illumination from the photographic lights to minimize their appearance in the copy photograph. The lights should be positioned at approximately 45-degree angles from the image plane, as with other reprography. Polarizing filters on the light sources can be used to suppress physical damage on the plate surface, so they may be useful for making publication-quality reproductions where the intent is to give the best possible representation of the image. (Fully polarized light reprography, with parallel filters on both sources and lens, results in a distorting increase in image contrast.) Similarly, photographing the plate while it is immersed in an inert solvent, such as heptane, may suppress reflections and physical damage. All such image modification techniques are inappropriate for photo-documentation of conservation treatments.

Colored tarnish films may be reproduced only poorly, or not at all, by color photographic materials. Color filters could be used to enhance the photographic reproduction of daguerreotype corrosion films, but no work has been published on this subject. Optimizing the specular reflection off the plate surface may allow tarnish films to be recorded more clearly.

A low-reflective black mask or shroud should be fitted to the camera lens barrel to reduce unwanted reflections in the plate. Use something like black felt mounted on cardboard or use an empty black photographic paper box -- 8 x 10 x 3 inches. A filter holder may be useful to arrange the mounting of the mask on the lens barrel. All ambient illumination in the room should be turned off to avoid unwanted reflections off the lens into the plate.

The mirror-like reflection from the plate will result in TTL light meters indicating exposure readings that are too large; reduce exposure by approximately 1½ stops from the indicated reading. (Incident light measurements are not subject to this adjustment.) Record the pretreatment exposure used and manually set the same exposure for mid- and post-treatment photographs; this is necessary, since exposure measurements taken from the plate may change as treatment proceeds.

See *Daffner; Kushel; Messinger (1996)* for details regarding the photographic recording of fluorescent patterns on daguerreotype plates.

2.3.3 PRESERVATION

Daguerreotypes, like all cased photographs, are composite artifacts having complex reactions to environmental conditions. Conditions that are optimal or harmless for one component may be damaging to another. Environmentally induced deterioration processes in one component may cause reaction products harmful to another component to be released.

2.3.3.1 Temperature

Heat alone is not a primary determinant of deterioration for daguerreotypes, although sustained elevated temperature may accelerate the corrosion of thiourea- or cyanide-cleaned plates. High temperatures may cause desiccation of case components. Very high temperatures can cause dimensional fluctuations that may contribute to image exfoliation on plates that have been excessively treated with gold.

Cycling ambient temperature produces the relative humidity cycles in the microclimate of the sealed package that are a major driving force behind the weathering corrosion of cover glass. The glass corrosion, in turn, causes metal corrosion on the plate.

Lower storage temperatures will retard deteriorative processes of paper and leather components. There is no reason why daguerreotypes cannot be housed in RH-controlled low-temperature storage areas. (These facilities must be equipped with appropriate transition climates to avoid transitory high humidity conditions when items are removed to normal temperature areas.)

2.3.3.2 Relative Humidity

In all types of cased objects, high relative humidity will contribute to deterioration of unstable glass, as well as corrosion of metal supports, mats and preservers. The leather, paper and wood components of cases will swell and shrink with fluctuating humidity, and they may become embrittled at low humidity. Leather can be structurally weakened at high humidity. Relative humidity above 60% can sustain mold growth.

High humidity can contribute to tarnishing and other corrosion processes of daguerreotype plates.

The major driving forces behind glass corrosion are moisture and fluctuations in relative humidity. Water (from moisture in the air) interacts on an atomic level with the glass surfaces, initiating glass corrosion cycles. Glass is best maintained at moderate relative humidity (40-50%) without excursions to higher or lower humidity.

For a mixed collection of daguerreotypes, ambrotypes and tintypes, 40% RH seems the best compromise condition. If possible, minimize the difference between the humidity conditions in the storage area and the areas where the objects are used for reference and display.

2.3.3.3 Environmental pollutants

Atmospheric pollutants can cause image deterioration in all types of cased objects. Sulphur dioxide, a common pollutant, can combine with oxygen and moisture to form sulphuric acid, which is particularly damaging to leather and paper. The silver image material of all cased photographs may be damaged by the ammonia, ozone, sulphur dioxide and nitrogen oxides generated in industrial environments.

The silver images of daguerreotypes react with airborne oxidizing gases.

A daguerreotype that is well sealed and boxed will be relatively free from harm by airborne pollutants. However, the source of corrosion-inducing pollutants may be the materials composing the package and case. These should be removed or isolated from the daguerreotype plate. Some preliminary investigations were done into the use of an activated charcoal "scavenger" within the daguerreotype package. (See *Mustardo.*)

2.3.3.4 Light

Although daguerreotype images are not sensitive to light, the pigments used for hand-coloring are frequently quite fugitive. The paper and textile components of the packages may also be light sensitive. Daguerreotypes with broken glass or seals may have an increased potential to tarnish if they are strongly lit and kept in a polluted atmosphere because light accelerates the formation of silver sulphide in the presence of unreduced sulphur gases.

2.3.3.5 Storage containers

Packaged daguerreotypes may be stored flat inside Solander boxes equipped with Ethafoam layers cut out to create cavities in which the cases fit snugly. The interior surface of the cavity is lined with a fine unbleached cotton textile to provide a nonabrasive surface. In boxes containing daguerreotypes, the interior of the Solander box lid may be lined with Pacific Silver Cloth (or equivalent) to provide a scavenger for oxidative gases entering the box (also, see "zeolites" below); the brown cloth also provides a dark surface to reflect on the daguerreotype images for optimal viewing.

Alternately, custom-made individual matboard boxes of the clamshell or slipcase variety may be constructed to house daguerreotypes. A four-flap enclosure adapted for housing cased photographs is used at the Harry Ransom Humanities Research Center. (*Brown, 1996*) This method is well-adapted for storing cased photographs on their edges, a measure recommended by some conservators to reduce glass corrosion-induced damage on the plate surface.

Padded plastic wrappings should be used only with caution. One instance has been noted of severe corrosion of daguerreotypes caused by the off-gassing of plasticizers used in plastic wrapping, even though these were described as "archival." However, food-grade polyethylene "zip-lock" bags have been successfully been used to store polished silver objects. As long as appropriate tests are carried out on the specific product used, these may provide inexpensive and effective protection for stored daguerreotypes. Conditioned sheet-form silica gel might be included in the bags as a humidity buffer. Likewise, boards and papers containing molecular sieves (zeolites) may be included in closed packages to sequester oxidizing gases.

2.3.4 TREATMENT

In the following section, it is assumed that all treatments will be carried out by qualified conservators familiar with the materials and characteristics of the objects they are treating. No treatment indications given here can be considered safe for any object without suitable testing, careful observation and skilled, judicious application.

Note that plates that were not gilded have particularly fragile image surfaces. Nongilded plates sometimes show lower apparent image contrast, or they may show more areas of physical image loss than gilded plates. However, it is usually necessary to resort to instrumental analysis, such as X-ray fluorescence spectroscopy, to determine the presence or absence of gold.

Note that some connoisseurs consider the presence of coherent tarnish layers on the periphery of a daguerreotype image to be an enhancement of the aesthetic qualities of the object, particularly when the tarnish shows a series of smoothly gradated interference colors. The decision to remove such tarnish should be made only by a fully informed owner/custodian. In many cases, such tarnish films should not be removed. The presence of original and intact sealing materials should also weigh heavily against a decision to open a package in order to perform cosmetic treatments.

2.3.4.1 Dusting

Plates that do not exhibit exfoliation can be dusted to remove loose debris. The preferred method is to use a gentle stream of air from a rubber bulb syringe. Alternately, a controlled low-pressure stream of air can be had from the airbrush attachment on a suction table. A clean airbrush should be reserved exclusively for cleaning daguerreotypes, and its air hose should be equipped with a moisture trap.

2.3.4.2 Washing and drying

To remove adhered accretions and some of the transferred products of glass corrosion, uncolored daguerreotypes may be safely washed in distilled/deionized water or in a pH 8.5-10.0 solution of ammonium hydroxide in distilled/deionized water. Five to fifteen minutes of immersion accompanied by gentle agitation of the wash tray will be sufficient to remove many water soluble accretions. The alkaline wash should be followed by a brief rinse in a bath of distilled/deionized water. This is followed by two or three rinses or an immersion in very clean absolute ethanol. (Some conservators use acetone instead of ethanol or follow the ethanol rinse with an acetone rinse.) Set the plate upright at a slight angle with a blotter underneath the bottom edge to drain. Note that there is a tendency for water to condense in tiny droplets on the plate surface during the alcohol/acetone evaporation when the ambient relative humidity is high enough; if this happens, use a gentle stream of warm air from a hair dryer to warm the plate while the solvent evaporates. Always apply the warm air stream to the verso surface of the plate rather than risk blowing dust particles onto the image surface. The daguerreotype surface can be permanently marred by drying marks, so drying must be carried out very carefully.

Colored daguerreotype plates can sometimes be immersion washed in heptane to dislodge the surface particles not dislodged by dusting; careful color testing is required. Before undertaking this procedure, consider whether it is likely to provide useful cleaning.

2.3.4.3 Chemical cleaning methods

The most common method used to remove tarnish from daguerreotypes has been the application of a "silver-dip," a solution designed to remove tarnish from ornate silver objects. These solutions were originally made of cyanide compounds and, after the early 1950s, were made of thiourea in a mineral acid. Both cyanide cleaners and thiourea cleaners etch the daguerreotype plate, causing irreparable damage to the plate's surface, and leave behind insoluble compounds; these residues initiate new corrosion on the daguerreotype surface. Such methods should never be used. See *Edmondson; Barger (1993).*

2.3.4.4 Aluminum tray electrolytic cleaning

Silver corrosion products may be removed by electrolytic cleaning in an aluminum tray filled with an ammonia solution. Use an uncoated aluminum baking container. The most concentrated solution of ammonia that can be used in the procedure is prepared by adding one part concentrated ammonium hydroxide (approximately 30%) to two parts of distilled/deionized water. (Note that a fume hood is necessary.) Slower cleaning actions will be obtained by using weaker concentrations of ammonium hydroxide. The daguerreotype plate is placed face up in the aluminum tray; the copper surface of the daguerreotype must be close to the aluminum tray for the electrolytic cell to be established. The ammonia electrolyte is poured into the tray to cover the daguerreotype. The corrosion product removal can be monitored visually as it proceeds. Hydrogen bubbles are evolved from the aluminum as cleaning proceeds. As grey oxides build up on the aluminum surface underneath the plate, the rate of cleaning will decrease; it may be necessary to move the plate to another position in the tray to allow cleaning to proceed. The reaction rate can be slowed by using a more dilute electrolyte or by using a smaller aluminum tray.

Note that the cleaning action progresses from the edge of the plate inwards towards the center of the plate. This may mean that a full-plate daguerreotype cannot be completely cleaned using this method.

Electrolytic cleaning might be used as a preliminary step before considering a decision to proceed with electro-cleaning (see below).

Electrolytic aluminum tray cleaning should not be used on ungilded plates.

2.3.4.5 Electro-cleaning

Electro-cleaning, as outlined in *Barger; Giri; White; Edmondson (1986)*, is based on a well-tested method for cleaning metal that has been adapted for the special requirements of daguerreotypes. In this process, the daguerreotype plate is made to be one electrode of a direct current electrical circuit; the second electrode is a silver wand used to direct the cleaning action. The circuit is completed by placing the daguerreotype and wand in a solution of ammonium hydroxide. The wand and plate do not directly contact each another. When a reversible DC current is applied through the circuit, cleaning is effected by forming and dissolving layers of silver oxide in a controlled manner.

The method leaves no chemical residues on the plate surface. The method produces a *micropolishing* effect, in which tiny irregularities in the silver surface are evened out by a combination of silver removal and redeposition on a very small scale. This leaves the plate less susceptible to future corrosion.

Some conservators have reported the appearance of translucent white "veils" overlying previously tarnished image areas after the application of electro-cleaning. The nature of this phenomenon is unclear.

It has been suggested that copper ions, released into the electrolyte solution during cleaning, might be redeposited on the image surface. *(Heller, 1988)* While this seems unlikely to happen, given the electrochemistry of the system, the suggestion has been made that the copper surface of the plate be "stopped out" with silicon rubber before treatment. (Note, however, that most silicon sealants evolve acetic acid as they cure.) The significance of silver redeposition is also the subject of some debate.

The procedure is carried out (in a fume hood) using a glass tray filled with an electrolyte solution made of one part concentrated ammonium hydroxide (approximately 30%) added to two parts of distilled/deionized water. A DC power source should produce between 2-5 DC volts. Cleaning action should be controlled by monitoring the current read on an ammeter in the circuit. The current is determined by the distance between the end of the wand and the daguerreotype plate surface; in both anodic and cathodic phases, the current should be maintained in the range of 8-25 milliamperes (mA). Regular switching of the current direction is nescessary for the cleaning action to take place. If some mechanical action is required to move the loosened tarnish products off the plate surface and into the solution, this should be done with a soft brush or by using an rubber bulb syringe to force a stream of electrolyte over the surface while cleaning. The direction of the brushing action should be the same as that of the final polishing marks. Heavily tarnished areas may be susceptible to abrasion.

Contact between the silver wand and the plate during cleaning will produce sudden increase in current and will damage the image. Such current surges can be prevented by using a constant-current power source or by adding appropriate fuses or resistors to the device.

Electro-cleaning cannot be used on hand-colored daguerreotypes or on plates that have not been gilded.

2.3.4.6 Hydrogen plasma reduction cleaning / physical sputter cleaning

Two variations of cleaning daguerreotypes using plasmas have been used for a number of years in Europe. Hydrogen plasma reduction cleaning results in oxidized silver being chemically reduced to silver metal. Physical sputter cleaning uses a chemically inert gas plasma, such as argon, to physically remove corrosion from the daguerreotype surface. These methods may be applied to hand-colored daguerreotypes. Both require sophisticated equipment to contain the plasma, and to create and maintain a high vacuum environment, as well as specialized operating technicians.

While several groups researching both these methods have observed that some daguerreotypes treated in plasmas develop white surface films, it seems that the hydrogen plasma cleaning procedures do not produce microetching in the silvered surface. The advantage of hydrogen plasma reduction cleaning over other cleaning methods is that oxidized silver is reconverted to silver, not removed from the plate.

2.3.4.7 Repackaging of plates

See Section 2.2.3.9

2.3.4.8 Resealing

See Section 2.2.3.10

2.4 AMBROTYPE PLATES

2.4.1 PROCESS

Ambrotypes are direct positive photographs produced in the camera on a transparent or colored glass plate. The glass is coated with collodion (a cellulose nitrate solution), which is then sensitized, exposed and developed. Physically developed silver forms the image highlights; this image silver was made to appear lighter in color by using diluted developers, development retarding agents, whitening agents (such as mercuric chloride) or cyanide fixers. After development, the image is fixed, dried and varnished. Placed against a dark background (fabric, paper, pigmented lacquer), the light colored silver image appears as a positive. Sometimes the collodion was left unvarnished. Paints or dry colours may have been applied before or after varnishing.

An albumen substrate layer was sometimes used to improve the adhesion of the collodion to its glass support.

The image-carrying layer may be on the surface of the glass closest to the viewer, in which case the image will be laterally reversed and the package will require a cover glass. These may be referred to as "double plate" ambrotypes. Sometimes the plate is positioned with the image-carrying layer on the interior side of the package; this corrects the image reversal and eliminates the need for a cover glass. These may be called "single plate" ambrotypes.

The arrangement and treatment of the various layers inside the ambrotype package were subject to many variations. ("Ambrotype" originally referred to an American variant patented by James Ambrose Cutting. Other variants of the process were called alabastrine process, amphitype, lampratype, relievo.)

Ambrotypes were sometimes made on blue-, red-, orange-, green- or purple-colored glass (the latter being called "Bohemia glass" or "ruby glass"). Ambrotypes made on dark-colored glass do not require a dark backing. One contributor observes that these plates are often unvarnished and, as a result, show more extensive silver image deterioration.

Ambrotype plates may be adhered overall to another plate of glass with Canada balsam, a natural resin adhesive. (This is the subject of the Cutting patent.)

In the relievo variant, all of the image-carrying layer representing the mid-tone background behind a portrait subject was scraped away. This allowed the figure to "float" on the dark field of the added backing and lent a sense of depth to the subject.

2.4.2 CONDITION

2.4.2.1 Glass support

(For notes on the condition of nonadhered cover glass, see Section 2.2.2.3.)

The glass used to make ambrotype plates was usually commercially available pane glass. There were some companies that sold "photographic" glass -- this meant that the glass was free of physical flaws and was relatively colorless, not that the glass had superior durability or corrosion resistance.

Glass supports of all types are susceptible to physical damages such as breaking and chipping.

Some glass formulations are chemically unstable due to a high flux content, especially those with a high ratio of sodium flux in proportion to the alkaline earth flux (calcium and magnesium oxide). Note that glass with a high sodium content produces a yellow-orange fluorescence under UV illumination, whereas glass with a higher alkaline earth content tends to produce orange-magenta fluorescence. Glass corrosion is caused by inherent instability linked to unfavorable environmental conditions.

Writing about the condition of glass in collodion wet-plate negatives, M. H. McCormick-Goodhart states, "The collodion and varnish coatings applied to the glass typically prevent the image bearing side of the plate from exhibiting the 'weathered' or 'weeping' glass appearance observed on daguerreotype cover glasses. Nevertheless, alkali leaching from the glass and diffusing into the collodion and varnish layers promote chemical changes in the coatings. The weakened coatings are prone to crazing, cracking, flaking and gradually increasing varnish saponification even though just a small fraction of the glass substrate is involved in the reaction. A hydrated 'silica-rich' layer forms at the original collodion-glass interface, and this layer may also contribute directly to the collodion's adhesion quality, because it is microporous and hygroscopic in nature." (*McCormick-Goodhart, "Glass Corrosion . . .," 1992*, p. 264)

2.4.2.2 Collodion image-carrying layer

Collodion film is a form of cellulose nitrate produced from a solution of pyroxylin (cotton treated with mineral acids) dissolved in ether and alcohol. Collodion is soluble in many organic solvents.

Unvarnished collodion is extremely susceptible to mechanical abrasion. The collodion binders of ambrotypes and tintypes may be chemically unstable, particularly if excess alcohol was used in preparing the solution. Ambrotype collodion layers may be chemically altered by glass corrosion at the glass-collodion interface (see above). All these influences may result in the collodion layer cracking or flaking. Collodion may yellow and become more opaque with age, causing a decrease in image contrast.

2.4.2.3 Silver image

The physically developed silver particles of ambrotypes are larger than the colloidal photolytic silver particles typical of printing-out processes.

Normally the silver images of ambrotypes, when properly processed, do not fade or discolor. However, they may exhibit silver corrosion, especially if the image is unvarnished.

Residual processing chemicals in the collodion layer, especially sodium thiosulfate, may cause staining and fading of the silver images. One contributor has observed instances of ambrotypes which have converted to a bright yellow color.

2.4.2.4 Coatings (pigmented lacquer and clear varnish)

Pigmented lacquer (frequently made from lamp black pigment mixed in bitumen, asphaltum or linseed oil) was often used on the verso side of the clear glass support. Deteriorated lacquer may exhibit crazing and flaking, especially if it contains asphaltum. Deteriorated lacquer may also damage the collodion image layer if these layers are adjacent.

Many ambrotypes have a clear varnish applied on the collodion image layer; white shellac, dammar, sandarac and copal were commonly used. The varnish saturates the image by increasing gloss, and protects the underlying collodion layer and its silver image from physical damage and chemical deterioration. Ambrotype varnishes are applied as "spirit varnishes" which have a small amount of varnish resin dissolved in a solvent. The varnish was flowed onto the collodion image surface, forming a film considerably thinner than a brushed varnish.

Varnishes may be chemically altered by glass corrosion at the glass-collodion interface (see Section 2.4.2.2 above). Deteriorated varnishes may exhibit discoloration, crazing, flaking or partial liquefaction (saponification). They may also damage or obscure the underlying image layer. Varnish layers can lose gloss and accumulate dirt and grime. Dust can scratch and abrade the varnish and binder layers during handling.

The solubilities of the collodion image layer and the varnish are typically very similar, and the collodion is very easily abraded, so it is likely that any attempt to remove a discolored varnish will also remove some image-carrying layer.

2.4.2.5 Paint/pigment components

Pigments may be applied to ambrotypes in several ways and using various binding media. If watercolors are used, these will require the addition of a suitable wetting agent, such as ox-gall. Paints may be applied over the image-carrying layer or behind the glass support. In the case of "flipped" plates, where the image is seen through the glass support, the hand-coloring applied to the image-carrying layer will be seen through the collodion silver image. Colorants are sensitive to light, moisture and abrasion. "Shell gold" (metal powder in oil or gum arabic solution) was used to highlight selected image areas, such as buttons and jewellery.

2.4.3 PRESERVATION

Cased photographs are composite artifacts having complex reactions to environmental conditions. Conditions that are optimal or innocuous for one component may be damaging to another. Environmentally induced deterioration processes in one component may cause the production of reaction products harmful to another component.

2.4.3.1 Temperature

Cycling temperatures may produce interlayer cleavage of weakly adhered layers due to differences in dimensional response. High temperatures may cause desiccation and may promote the deterioration of inherently unstable collodion layers, lacquer and varnish layers. Lower storage temperatures will retard deteriorative processes of paper components and collodion binders but will not dramatically benefit either the silver image or the glass support. There is no reason ambrotypes cannot be housed in RH-controlled low-temperature storage areas. (These facilities must be equipped with appropriate transition climates to avoid transitory high humidity conditions on removal to normal temperature areas.)

2.4.3.2 Relative humidity

In all types of cased objects, high relative humidity will contribute to deterioration of unstable glass, as well as corrosion of metal supports, mats and preservers. The leather, paper and wood components of cases will swell and shrink with fluctuating humidity, and they may become embrittled at low humidity. Leather may be structurally weakened at high humidity. Relative humidity above 60% can sustain mold growth.

The major driving forces behind glass corrosion are moisture and fluctuations in relative humidity. Water (from moisture in the air) interacts on an atomic level with the glass surfaces, initiating glass corrosion cycles. Glass is best maintained at moderate relative humidity (40-50%) without excursions to higher or lower humidity.

High humidity may accelerate the deterioration of the inherently unstable collodion layers of ambrotypes.

For a mixed collection of ambrotypes, daguerreotypes and tintypes, 40% RH seems the best compromise condition. If possible, minimize the difference between the humidity conditions in the storage area and the areas where the objects are used for reference and display.

2.4.3.3 Environmental pollutants

Atmospheric pollutants can cause image deterioration in all types of cased objects. Sulphur dioxide, a common pollutant, can combine with oxygen and moisture to form sulphuric acid, which is particularly damaging to leather and paper. The silver image material of all cased photographs may be damaged by the ammonia, ozone, sulphur dioxide and nitrogen oxides generated in industrial environments. Sulphur and nitrogen compounds can cause deterioration of the collodion binder. (Most ambrotype plates are largely protected from contact with pollutants by the clear varnish layer.)

Varnished ambrotype images that are well sealed and boxed will be relatively free from harm by airborne pollutants. However, the source of corrosion-inducing pollutants may be the materials composing the package and case. These should be removed or isolated from the image-carrying layer.

2.4.3.4 Light

Silver image particles are generally not sensitive to light. However, as with all organic films, the collodion layer may be somewhat light sensitive. More seriously, light is damaging to the natural resin varnishes used on ambrotypes.

The pigments used for hand-coloring and the textile components are frequently quite light sensitive.

2.4.3.5 Storage containers

Cased photographs may be stored flat inside Solander boxes equipped with Ethafoam layers cut out to create cavities in which the cases fit snugly. The interior surface of the cavity is lined with a fine unbleached cotton textile to provide a nonabrasive surface.

Alternately, custom-made individual matboard boxes of the clamshell or slipcase variety may be constructed to house cased ambrotypes. A four-flap enclosure adapted for housing cased photographs is used at the Harry Ransom Humanities Research Center. (*Brown, 1996*) This method is well-adapted for storing cased photographs on their edges, a measure recommended by some conservators to reduce glass corrosion-induced damage on the plate surface.

Note that the inclusion of paper or cardboard inside containers provides some buffering capacity to modulate humidity fluctuations. Appropriately conditioned silica gel-containing sheets may be useful inside sealed containers for establishing stable humidity conditions. Materials containing molecular sieves (zeolites) can absorb pollutants that might otherwise produce deterioration in photographs.

2.4.4 TREATMENT

In the following section, it is assumed that all treatments will be carried out by qualified conservators familiar with the materials and characteristics of the objects they are treating. No treatment indications given here can be considered safe for any object without suitable spot testing, careful observations and skilled, judicious application.

2.4.4.1 Repair of broken plates

Ambrotypes with broken glass supports are difficult to repair for several reasons:

- adhesives appropriate for glass repair may be reactive with the image components of the ambrotypes;
- the edges to be mended require preparation with detergents or degreasing agents, which can have deleterious effects on image components;
- it may be difficult to align the broken pieces without damaging the image layer or the pigmented lacquer;
- repairs to broken glass supports are generally quite visible.

While there are several epoxy adhesives with a similar refractive index to that of glass, these are not generally suitable for ambrotype plate repair because accidental spread of the adhesive on the image layer during application cannot be safely removed. In addition, epoxies of this type generally have poor aging characteristics.

Acryloid B-72 is a methyl methacrylate polymer which has been used successfully to repair glass plate negatives. While the bond formed is relatively weak and there may still be problems with removing excess, this adhesive is nonyellowing and reversible. If the mend must be removed, this can be done by either warming the joint sufficiently to soften the adhesive or using a nonpolar solvent such as toluene.

The ideal adhesive for repairing broken ambrotype plates would use a cleanup solvent that does not interact with the image-carrying layer or coatings, would be reversible and nonyellowing, would form a strong bond with glass and would match the refractive index of glass. (A new consolidating resin, poly(2-ethyl-2 oxazoline), also called "Aquazol-50" or "P-Ox," should be tested in this application. See *Wolbers; McGinn; Duerbeck.* Painted Wood: History and Conservation, *Williamsburg, Va., Nov. 11-14, 1994, conference abstract, p. 40.*) Until such an adhesive is available, conservators may choose to only stabilize broken ambrotypes with passive measures -- by placing them in secure housing such as a custom sink mat.

2.4.4.2 Dusting

Dust may be removed from unvarnished collodion with a gentle stream of air from a rubber bulb syringe. These unprotected collodion surfaces are generally too fragile to tolerate any contact. Care should be taken not to dislodge the loosely bound hand-coloring.

Varnished collodion that exhibits no signs of flaking or deterioration may be gently brushed to remove dust. Begin by brushing the glass surface with a long-haired soft brush while holding the plate firmly in one hand. Always brush from the centre of the plate outward. This will reduce disturbance to damaged or abraded emulsion at the edges.

2.4.4.3 Cleaning

Ambrotype plates in good condition may sometimes be cleaned with water or organic solvents, although careful spot testing is imperative. Although immersion treatments have been reported, controlled application of cleaning solutions with cotton swabs or small brushes may be safer.

Collodion and spirit varnishes are often soluble in alcohols and acetone. Deteriorated collodion may also be sensitive to water. Another consideration is the possible presence of an albumen substrate. If present, the albumen may absorb some water, causing the collodion emulsion to lift. Water may also cause blooming in the varnish layer. The presence of hand-coloring may be a further complication. This may have been applied to either the collodion image-carrying layer, underneath the varnish, or may be applied to the varnish surface.

Alkaline solutions may alter the silver images of ambrotypes and should be avoided. Ketone and aromatic hydrocarbon solvents will risk solubilizing the varnish and collodion layers. Spot testing may establish that hexane, mineral spirits, naphtha, petroleum benzine, trichloroethylene or trichloroethane can be used.

2.4.4.4 Pigmented lacquer layer -- consolidation; inpainting losses

Any attempt at consolidation, inpainting or removal of the pigmented lacquer will be greatly complicated by the presence of an underlying collodion image-carrying layer and albumen sublayer. (See next Section.) Thus, it is important to determine if the lacquer has been applied directly to the collodion layer or is on the uncoated glass side of the support. Acryloid B-72 in xylene (15-20%) may be appropriate for consolidation of a lacquer layer adjacent to a collodion layer. (Two or three applications may be necessary to effect consolidation.) Heptane or petroleum benzine might also be tested as solvent vehicles for the consolidating resin.

If the damaged lacquer layer is located on the uncoated glass side of the support, consolidation with a local application of an appropriate adhesive will be simpler. Likely candidates for this are Klucel G (hydroxypropyl cellulose) in alcohol or Acryloid B-72 in xylene.

Another possibility for lacquer consolidation is the use of a solvent chamber to deliver solvent vapors. Testing the safety of such a procedure may be difficult.

A backing of acrylic black velvet may be used to reintegrate missing sections of lacquer without having to remove original material. Alternatively, a backing of good-quality black paper (Arches Cover Black for example) along with an interlayer of Mylar Type D (3 or 5 mil) provides the high gloss and blackness necessary for this type of minimal-intervention reintegration. The lacquer is generally an original component of the object, and this must be a consideration in any decision to remove and replace it. However, if deterioration is so severe that complete removal is judged to be the best treatment option, the black layer may be replaced by velvet, paper/Mylar or by re-painting the glass surface with an appropriate paint.

Small losses to the lacquer have been successfully inpainted with watercolor or with acrylic resin paints. Acrylic resins may be dispersed in heptane or petroleum benzine for this purpose. Reversibility and compatibility with the existing coating must be considered. (Refer to *Photographic Materials Conservation Catalog*, Chapter 4 -- "Inpainting of Historic Photographic Prints" for comments on specific inpainting materials.)

2.4.4.5 Collodion image-carrying layer -- consolidation

The thin collodion layer on an ambrotype, if it is found to be in poor, unstable condition, will be extremely difficult to successfully consolidate. The possible presence of an albumen sublayer further complicates the approach. The usual caution conservators exercise in approaching treatment options must be doubled in these instances.

Careful spot testing is imperative before consolidation can be undertaken. Weak gelatin and methylcellulose solutions (applied with a brush) may be used to readhere flaking collodion to its underlying glass support. Alternatively, Acryloid B-72 in xylene may be used. It may be possible to disperse the acrylic resin in heptane or petroleum benzine for this purpose. One conservator has reported success using heat-activated PVA resin -- AYAF, 5% in ethanol. (*Baas, 1982*) In all cases, the application of consolidants should be considered irreversible.

It may be possible to readhere flaking collodion with solvent vapor applied in a solvent chamber.

Overall applications of varnish as a consolidation treatment are not recommended.

2.4.4.6 Collodion image-carrying layer -- inpainting losses

There is little published research concerning the inpainting of ambrotypes and tintypes.

Dry pigments mixed with an acrylic resin, such as Acryloid B-72 (soluble in nonpolar solvents), have been successfully used to inpaint ambrotypes. Consider dissolving the resin in heptane or petroleum benzine for this application. Klucel G (hydroxypropyl cellulose) and Soluvar Matte Varnish have also been suggested as inpainting media. An appropriate isolating layer should be used beneath all inpainting. (Refer to *Photographic Materials Conservation Catalog*, Chapter 4 -- "Inpainting of Historic Photographic Prints" for comments on specific inpainting materials.) One contributor reports successful use of pastel dust applied without any vehicle using a very soft bristle brush. The pastel dust can be removed, if necessary, with a nonpolar solvent or by simply blowing it away.

2.4.4.7 Repackaging plates

See Section 2.2.3.9

2.4.4.8 Resealing

See Section 2.2.3.10

2.5 TINTYPE PLATES

2.5.1 PROCESS

Tintypes are direct positive photographs produced on a lacquered iron plate. Usually both sides of the metal plate were coated with the black (or brown) pigmented lacquer (sometimes called "japanning" or "Japan varnish"). One side of the plate is subsequently coated with iodized collodion. The wet collodion layer is then sensitized, exposed and developed. Physically-developed silver particles form the image highlights; this image silver was made to appear lighter in color by using diluted developers, development retarding agents, whitening agents (such as mercuric chloride) or cyanide fixers. Against the dark lacquered plate, the image appears as a positive. After development, the collodion image is fixed, dried and varnished. Hand-coloring may be applied before varnishing.

The images are laterally reversed. Multiple images of the same subject could be produced with a multiple-lens camera, such as a carte-de-visite camera.

Tintypes may be cased, as with ambrotypes and daguerreotypes, but more commonly they are found completely unhoused or in a paper window mat. Tintypes are often found mounted in specially manufactured tintype albums. Small tintypes were sometimes mounted in jewellery.

The tintype process and its variants were used well into the twentieth century. Later versions of the process used gelatin silver emulsions on both lacquered metal and black paper supports.

2.5.2 CONDITION

2.5.2.1 Iron support

All types of metal supports are subject to mechanical distortion from bending or other mechanical working. The thin, flexible iron sheet of the tintype is particularly vulnerable to folding and bending, which frequently results in damage to overlying layers.

Rust (iron oxide) is the most serious deterioration encountered on tintypes. This may occur at the edge of the plate, where the plate is more exposed to the environment. Alternately, cracks and losses in the pigmented lacquer, collodion and varnish layers caused by mechanical distortion and physical damage (scratches, folds and bends) result in exposure of the iron plate. Rust formation will lead, in turn, to further losses in the overlying layers. Note that rust, unlike other metal corrosion products, is generally not stable or protective against further corrosion. Dust can contribute to the corrosion of the iron support by retaining moisture and other corrosion initiators.

A variant of iron corrosion is *filiform corrosion* that appears as irregular fine lines of corrosion products below the overlying layers. Tiny quantities of concentrated electrolyte solution formed by contaminants such as iron chlorides under the black lacquer layer move forward by capillary forces. This is generally seen as a series of raised trails under the image that are especially noticeable in raking light. The "head" of the trail is the site of active corrosion; it moves through the iron support, leaving behind a trail of corrosion products in its path. This type of corrosion appears active only in environments with relative humidity above 58%.

Iron oxides are more transparent to X rays than is iron. This difference could be used to determine the extent of corrosion that has occurred under the image and lacquer layers.

2.5.2.2 Pigmented lacquer layer

The iron support of the tintype was coated (usually on both sides) with a black or brown lacquer that frequently contained a combination of linseed oil (or mastic or copal resin), asphaltum and pigment. This was baked onto the iron surface. Filiform corrosion may occur beneath this lacquer coating. The lampblack used in some coating formulations can promote corrosion of iron.

2.5.2.3 Collodion image-carrying layer

Collodion film is a form of cellulose nitrate produced from a solution of pyroxylin (cotton treated with mineral acids) dissolved in ether and alcohol. Collodion is soluble in many organic solvents.

Collodion may be chemically unstable, particularly if excess alcohol was used in preparing the solution. These influences may result in collodion layer cracking or flaking. Collodion may yellow and become more opaque with age, causing a decrease in image contrast. Unvarnished collodion is extremely susceptible to mechanical abrasion.

2.5.2.4 Silver image

The physically developed silver particles of tintypes are larger than the colloidal photolytic silver particles typical of printing-out processes.

The silver images of tintypes, if properly processed, do not generally fade or discolor. However, tintypes may exhibit silver corrosion, particularly if the plate is unvarnished. Residual processing chemicals in the collodion layer, especially sodium thiosulfate, may cause staining and fading of the silver images.

2.5.2.5 Paint/pigment components

Paints, usually watercolors and gouache, are applied on the tintype surface after treatment with a suitable wetting agent, such as ox-gall. Colorants are sensitive to light, moisture and abrasion. "Shell gold" (metal powder in oil or gum arabic solution) was used to highlight selected image areas, such as buttons and jewellery.

2.5.2.6 Varnish

Clear varnishes were used as protective coatings for all photographs employing collodion image-carrying layers; white shellac, dammar, sandarac and copal were commonly used resins. The varnish saturates the image by increasing gloss, and protects the underlying collodion layer and its silver image from physical damage and chemical deterioration. Tintype varnishes are applied as "spirit varnishes" which have a small amount of varnish resin dissolved in a solvent. The varnish was flowed onto the tintype surface, forming a film considerably thinner than a brushed varnish.

Varnishes may lose gloss, become discolored, develop crazing or flaking, or accumulate dirt and grime. Deteriorated varnish may damage or obscure the underlying image layer. The abrasive nature of dust can scratch the varnish layer during handling.

Research has shown the collodion/varnish interface on tintypes to be an intermingled zone rather than a discrete separation. The solubilities of collodion and the varnishes are often very close, and the collodion is very easily abraded, so it is likely that any attempt to remove a discolored varnish would also damage the collodion image-carrying layer.

2.5.3 PRESERVATION

2.5.3.1 Temperature

Heat alone is not a primary determinant of deterioration for tintypes. Cycling temperatures may produce interlayer cleavage of weakly adhered layers due to differences in dimensional response. High temperatures will accelerate deterioration of inherently unstable collodion and varnish layers. Additionally, high temperatures may lead to loss of moisture and desiccation of paper and case components. Lower storage temperatures will retard deteriorative processes of paper components and collodion binders but will not dramatically benefit either the silver image or the iron support. There is no reason tintypes cannot be housed in RH-controlled low-temperature storage areas. (These facilities must be equipped with appropriate transition climates to avoid transitory high humidity conditions on removal to normal temperature areas.)

2.5.3.2 Relative humidity

Atmospheric moisture accelerates rust and filiform corrosion on the iron supports. High humidity may accelerate the deterioration of inherently unstable collodion.

Tintypes without cases may benefit from storage conditions below 40% RH. For a mixed collection of tintypes and cased photographs, 40% RH seems the best compromise condition. If possible, minimize the difference between the humidity conditions in the storage area and the areas where the objects are used for reference and display.

2.5.3.3 Environmental pollutants

Pollutants (especially sulphur and nitrogen compounds) can cause deterioration of the collodion silver images of tintypes, especially unvarnished plates.

A varnished tintype that is well boxed will be relatively free from harm by airborne pollutants. However, the source of corrosion-inducing pollutants may be the original housing materials. These should be isolated from the plate, if possible.

2.5.3.4 Light

Light is damaging to the natural resin varnishes used on tintypes.

The pigments used for hand-coloring are frequently quite fugitive. The paper components of the packages may also be light-sensitive.

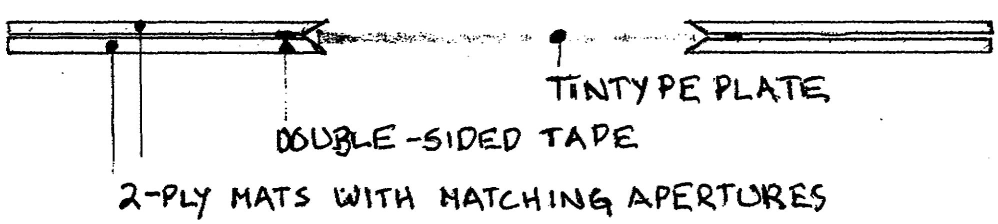
2.5.3.5 Storage containers

Cased tintypes may be housed in custom-made boxes as described above for ambrotypes and daguerreotypes. Tintypes in original paper mats may be over-matted in high-quality matboard window mats and stored in print boxes.

Unhoused tintypes may also be matted. One approach to securing the plate for matting is described in Section 2.5.3.6 below. Plates housed in this way can be fixed into a conventional window mat with a backboard and stored in a print box.

For a large collection of uncased tintypes that have no original paper mats, a novel storage method has been suggested by contributors M. Fischer and A. Robb. This is an adaptation of a common technique used by archaeological conservators. Iron and other metals are kept in a low-relative-humidity environment by placing them in airtight food containers (such as Tupperware or Rubbermaid) containing preconditioned silica gel desiccant to control the relative humidity. This technique would be particularly useful for tintype collections kept in historic house museums that cannot maintain low relative humidity. This housing also has the benefit of isolating the collection from harmful atmospheric pollutants. Use a good-quality plastic container, such as one made of polyethylene that has passed the Photographic Activity Test. The amount of desiccant used is determined by the volume of the container. The silica gel is packed into polyester netting or a pierced polyethylene bag. A humidity indicator card should be placed in the box so that the relative humidity levels can be monitored. The quality of the seal of the container, the number of times the box is opened, and the ambient humidity when the box is sealed will all effect the period before reconditioning of the silica gel is necessary. While this storage technique has not been tested, it shows promise and warrants testing.

2.5.3.6 Handling mat for tintypes



Outline the exact shape of the plate at the centre of two sheets of high-quality 2-ply matboard that are approximately three times the height and width of the plate. Cutting freehand, create bevel apertures in both sheets that follow the plate outlines precisely; the bevel should be exaggerated to provide a lip that will catch and hold the plate in a channel between the two sheets, as in the diagram on the previous page. Use 3M Double-sided Tape No. 415 to firmly attach the cardboard sheets together, creating a tight channel in which the perimeter of the tintype plate is held.

These units can be stored in boxes or be individually enveloped. For display, they can be hinged into a conventional 4-ply window mat and framed.

2.5.3.7 Plastic sleeves for tintypes

Unprotected tintype plates or plates mounted in decorative paper mats may be inserted into a plastic sleeve with a high-quality 2-ply matboard insert as a stiffener and a humidity buffer. Polyester, polyethylene and polypropylene are suitable plastics. Plates with flaking collodion binder or friable hand-coloring media should not be put in plastic sleeves.

The use of food-grade polyethylene "zip-lock" bags may be considered as an inexpensive and effective protective container for tintypes. Appropriate tests should be carried out on the specific product used. Sheet-form silica gel might be included as a desiccant.

2.5.4 TREATMENT

In the following section, it is assumed that all treatments will be carried out by qualified conservators familiar with the materials and characteristics of the objects they are treating. No treatment indications given here can be considered safe for any object without suitable spot testing, careful observations and skilled, judicious application.

2.5.4.1 Flattening

Some conservators have found that it is possible to flatten bent tintypes by burnishing the reverse with a smooth tool. Care must be taken to protect both front and reverse surfaces, perhaps with polyester film. Other conservators have successfully reduced the distortions of badly bent plates in a press, first sandwiching the plate between sheets of polypropylene and many layers of blotter; no visible damages were noted in the overlying layers when observed under magnification.

However, it may be that overlying varnish and collodion layers are weak or cracked in these bent areas; flattening the tintype may exacerbate the damage.

Contributors M. Fischer and A. Robb, while testing various treatments suggested for tintypes, found that flattening generally led to damage in the binder layer due to its extreme brittleness at room temperature. Their testing found that heating to increase the flexibility of the varnish layer during flattening does not greatly aid in the procedure. They found burnishing to not be particularly effective and to cause abrasions on the image layer.

Planar deformations can be left untreated and the (distorted) plate can be supported in a custom sink mat housing.

2.5.4.2 Iron support -- reduction of rust

"Rusted iron seems to be the worst possible thing conservators encounter." (*Brown et al., p. 137*) Unlike other corrosion products, rust does not serve as a protective barrier for the uncorroded iron beneath it. Corrosion occurs in areas exposed due to damage, along the exposed edge of the plate, and even under the black lacquer layer itself producing blind cleavage.

In treating iron corrosion, it is imperative to reduce the quantity of accumulated rust to a minimum before proceeding with any passivation, consolidation or coating steps. The removal or isolation of chloride contaminants is especially important since iron chloride is hygroscopic and produces a self-catalysed corrosion action. Chloride-induced corrosion is recognizable by its bright orange color. The presence of chlorides lowers the relative humidity threshold necessary for active corrosion from 60% to 40%.

The only suitable technique for rust reduction on tintype supports is mechanical removal with small instruments. (Rust reduction with enzyme agents and complexing agents has been reported, and may eventually prove useful in the treatment of rusted tintypes.) General problems with mechanical reduction include the fact that it will not remove all the rust and may also cause the loss of flaking sections of the collodion image-carrying layer. In addition, mechanical removal of rust exposes uncorroded iron that must now be protected from further corrosion. The newly exposed iron is also quite shiny and may have to be treated in some way to make it less obvious.

Fischer and Robb experimented with several mechanical instruments. They tested a scalpel blade and a micro-spatula on rust in an area of image loss; these resulted in evident scratches and removal was incomplete on a microscopic level. A softer material, such as a sharpened hardwood stick, resulted in incomplete rust removal but did not leave evident scratches.

2.5.4.3 Iron support -- passivation

The following section contains commentary and results derived from preliminary research on possible treatment options for tintypes carried out by contributors M. Fischer and A. Robb in 1992. None of the measures considered are current conservation treatment practices; they are offered here as a means of disseminating possible ideas for further research and testing.

Passivation is the production of an inert surface on a metal object that will not corrode in the future.

One approach to iron passivation uses tannic acid. The treated area darkens to a black color a day or two after application. Preparation of the surface requires that the area be degreased and stripped -- difficult procedures due to the solubilities of the binder and varnish layers. The tannin must be used in an acidic solution (pH 2-3). Once the iron-tannate complex is formed, a coating should be applied. Proper equipment/protection must be in place when using tannic acid, a suspected carcinogen. (See *Logan* or *Pelikán.*)

Pyrogallol (1,2,3-benzenetriol; 1,2,3-trihydroxybenzene; pyrogallic acid) can be used to form a protective blue/black pyrogallate layer on iron, similar in color to the lacquer. Care should be taken when using pyrogallol as the Merck Index considers it a poisonous substance. Two solutions of pyrogallol were tested by Fischer and Robb, one in water, the other in ethanol. The solvent carrier may cause problems to either the metal base, the lacquer or to the collodion binder layers. The method showed promising results; further testing of the material and technique is warranted.

Rust-Oleum Rust Reformer is a commercial product made by the Rust-Oleum Corporation of Vernon Hills, Illinois and is available in hardware stores. It consists of tannic acid in a water-based vinyl acrylic copolymer emulsion with diethylene glycol methyl ether. The addition of the vinyl acrylic copolymer appears to act as a consolidant and a glossing agent. This combination of corrosion reduction and consolidant in one step may not be desirable; the action of tannic acid may be incomplete due to the premature drying of the consolidant. This appears to have been the cause of blistering in surface coating testing on aged samples. First, the areas of corrosion must be reduced as much as possible; the product can then be applied sparingly to areas of active corrosion. The result is a glossy black that resembles tintype lacquer. If not applied carefully, an excess could be left on the image layer. Testing of this product by Fischer and Robb gave very good results but long-term effects are not known; further investigation is warranted.

Vapor phase inhibitors (VPIs) are compounds that invisibly coat the surface of a metal, excluding moisture and thus acting as a barrier. They require specific conditions to work, and little is known as to their effects on photographic images. Further testing may show them to be useful. One specific vapor phase inhibitor mentioned in *Davis* (p.18) that warranted testing was Daubert VCI, a paper impregnated with dicyclohexylammonium nitrate.

2.5.4.4 Iron support -- consolidation/coating

The following section contains commentary and results derived from preliminary research on possible treatment options for tintypes carried out by contributors M. Fischer and A. Robb in 1992. None of the measures considered are current conservation treatment practices; they are offered here as a means of disseminating possible ideas for further research and testing.

Since the entire iron support cannot be treated, corrosion reduction, passivation, consolidation, and coating treatments cannot fully stabilize the rusting tintype. They are really only local cosmetic treatments. Given this limitation, as well as the problematic nature of the materials used (solvents, water, heat), these consolidation treatments should be undertaken only after careful consideration. Rust reduction must be done before any attempt at consolidation, since corrosion products should not be trapped under the consolidant layer. The extent of the risks involved in using solvents, water and heat on tintypes is unresolved.

It is important to dry and degrease a metal surface before coating. Heptane may be an acceptable degreasing agent. The use of gentle heating (under 40° C) may be an acceptable drying treatment, although this may be problematic due to the differing thermal coefficients of expansion of the tintype layers.

Surface gloss factors may have to be considered when choosing a consolidant. Other critical factors may include aging characteristics and flexibility/strength of the consolidant.

Consolidants used by metals conservators on corroding objects include waxes, natural lacquers and synthetic products. Among waxes, microcrystalline wax is better than paraffin due to its superior water impermeability. Application of wax to a tintype may be difficult, especially in the delivery and the removal of any excess.

Polyvinyl acetate and acrylic resins in various solvents were tested by Fischer and

Robb as consolidants/coatings on a group of tintypes. Factors such as gloss, solubility of tintype components and degree of control were examined.

Polyvinyl acetate resins

- AYAT, 10% in toluene -- this gave the glossiest appearance.
- AYAF, 5% in ethanol -- severely flaking collodion emulsion may be locally consolidated with this solution; care must be taken as the collodion binder is soluble in ethanol.

Acrylic resins

Harder resins:

- Acryloid B-48N, both 10% and 20% (w/v) in xylene/ethanol (1/1) were investigated as consolidants; both mixtures gave a matt appearance and worked well as consolidants.

Intermediate hardness resins:

- Acryloid B-67, 20% (w/v) in petroleum benzine gave a glossy surface, but not as shiny as that produced by the 10% AYAT in ethanol.
- Acryloid B-72; this resin was not tested.
- Acryloid B-82; this resin was not tested.

Softer resins:

- Acryloid F-10, 10% (w/v) in petroleum benzine gave a matt appearance and seemed to work well as a consolidant. Consider that it is softer than the others tested and may not give the strength needed.

Those consolidants dissolved in ethanol or part ethanol flowed more rapidly and easily, which allowed less control. Consolidants in toluene flowed most slowly, making the application more manageable.

One source recommends applying graphite to the coated surface to form another protective layer that excludes moisture.

The materials noted above should serve as a guideline to what is available and how they might be used on tintypes. No particular polyvinyl acetate or acrylic resin can be singled out as a panacea for treatment.

2.5.4.5 Surface dusting

Dry cleaning is important because it can reduce dirt and grime while avoiding the problems associated with wet cleaning. However, reduction of dust and grime is problematic due to the potential of scratching the varnish and/or binder layers by the action of the dust or the device used to remove the dust. Flaking and cracked binder and varnish layers further complicate dry cleaning.

While brushing, apply pressure sparingly. Sometimes the electrostatic charge from the brush alone is enough to pick up any dust particles in sensitive areas. Brushing may not remove all of the imbedded dirt and grime.

Squirrel-hair brushes are among the softest western brushes. They are softer than cotton swabs and are not very resilient. A less resilient brush may be desirable when working in sensitive flaking areas. Different shapes and sizes of brushes should be considered.

When working with the brushes, one should work from the middle outwards. When working near cracks and flaking areas, hold the brush perpendicular to the damaged area to reduce any chance of contact. It may be advisable to work under a microscope when dealing with severely flaking tintypes.

Fischer and Robb experimented with the use of erasers and eraser crumbs; they do not recommend their use for dry cleaning of tintypes. They also experimented with cotton swabs, aspirators and blowers; they felt these provided less control than brush cleaning.

2.5.4.6 Surface cleaning

Cleaning with organic solvents or aqueous solutions has the potential to remove embedded dirt and grime that cannot be removed by dusting. However, the potential for damaging the tintype is greatly increased in comparison to dusting; the varnish, collodion binder and iron support might all be damaged. Water contributes to the corrosion of the iron support. Many organic solvents will solubilize the varnish, the collodion binder or both. Note that tintypes were made in different ways by varying methods and materials, and that this variability makes any generalization concerning their solubility characteristics impossible.

The issue of whether surface cleaning of a tintype with solvents or aqueous solutions should be attempted is unresolved. *McCabe (1991)* states that "Washing collodion plates can be very damaging and should not be attempted." Fischer and Robb also discourage cleaning with either organic or aqueous solvents.

The choice of delivery method for the cleaning agent is another complicating factor in wet cleaning. Despite their abrasiveness, cotton swabs are most commonly used because of the swab's ability to pick up and retain dirt. The abrasive nature of cotton in this context cannot be understated. Often the swelling action of the cleaning solution can make the varnish and/or collodion surface more sensitive to abrasion. Fischer and Robb also observed that dark areas (that is, nonsilver areas) are especially sensitive to abrasion.

Fischer and Robb have tested the following solvents and solvent mixtures for liquid cleaning of tintypes: water, ethanol, water/ethanol (1/1), water/ethanol (25/75), petroleum benzine, heptane, acetone, xylene, and toluene. It would appear from their testing that ketone and aromatic hydrocarbon solvents should be avoided. Water did not appear to harm these layers, but its use is problematic as far as the iron support is concerned. Alcohols and short-chained aliphatic hydrocarbons may have less effect on varnish and collodion layers but can still cause damage if wrongly applied or applied to sensitive areas. (Naphtha should be included in solvent testing.)

2.5.4.7 Pigmented lacquer layer -- consolidation; inpainting losses

See Ambrotype treatment, Section 2.4.4.4.

2.5.4.8 Collodion image-carrying layer -- consolidation

See Ambrotype treatment, Section 2.4.4.5.

2.5.4.9 Collodion image-carrying layer -- inpainting losses

See Ambrotype treatment, Section 2.4.4.6.

2.6 GLOSSARY

Alabastrine process -- a variant of the **ambrotype** process, using mercury chloride bleaching
Ambrotype -- a collodion silver photograph on glass; a direct positive camera original
Amphitype -- among other things, a process similar to **ambrotype** but using albumen
Binding tape -- an alternate term for **sealing tape**
Case -- a hinged box holding an **ambrotype**, or an American or British **daguerreotype**
Clasp -- brass hardware on a **case** that secures the closure of the hinged case cover
Collodion -- binder layer of **ambrotypes, tintypes**, and wet-plate negatives
Collodion positive -- term used in Britain for **ambrotype**
Cover glass -- protective glazing used on **daguerreotypes**, and some **ambrotypes** and **tintypes**
Cushion -- cardboard, cotton fibre and textile pad fixed to the inside surface of the case cover
Daguerreotype -- a photograph with silver image particles on a silvered copper plate
Deliminator -- an alternate term for a metal **mat**
Ferrotype -- an alternate term for **tintype**
Gilding -- a step in **daguerreotype** processing in which gold is added to the image particles
Hinge -- paper, leather or metal attachment between the case cover and **tray**
Lacquer -- a pigmented paint layer, used on both **ambrotypes** and **tintypes**
Lampratype -- a variant of the **ambrotype** process
Mat -- paper or metal sheet with an aperture cut in its centre
Melainotype, melanotype -- alternate terms for both **ambrotype** and **tintype**
Package -- plate and housing components forming a sealed unit; may be **cased** or framed
Pad -- an alternate term for **cushion**
Pannotype -- a collodion positive, similar to a **tintype**, but on black waxed textile or leather
Passe-partout (package) -- a **daguerreotype** housing format common in Europe
Perfling -- an alternate term for **retainer**
Pinchback -- an alternate term for **preserver**
Pinch pad -- an alternate term for **retainer**
Preserver -- for cased objects: brass foil that is folded around the edges of the plate package
Relievo -- a variant of the **ambrotype**, in which the background image areas are scraped away
Retainer -- velvet and cardboard strip lining the edge of the case **tray**
Sealing tape -- strip adhered at the perimeter of a **package** and holding the components together
Stereograph -- a two-image photograph which represents its subject three-dimensionally
Tintype -- a collodion silver photograph on an iron plate; a direct positive camera original
Tray -- the half of the **case** opposite the cover, which receives the **package**
Union case -- a **case** made of an early thermoplastic material

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