Introduction

Photographic materials have complex physical and chemical structures that present special preservation challenges to the librarian and archivist. Since the birth of photography in the late ۱۸۳۰s, many different photographic processes and materials have been utilized, each subject to deterioration through time and with use. Although deterioration is an ongoing natural process, nevertheless much can be done to slow the rate at which it takes place in photographs.

Deteriorated photographs may require specialized conservation treatment by a professional photograph conservator, often a costly, skill-demanding, and time-consuming procedure. For the majority of photographs in research collections, single-item conservation of deteriorated photographs is probably not a feasible or a cost-effective preservation solution. Instead, preventive conservation actions such as maintenance of a good environment, promoting proper care and handling through staff and user education, and the use of good quality storage housings, will have a more lasting, positive impact on the preservation of a collection.

This publication is intended to provide a basic understanding of how and why photographs deteriorate and what can be done to slow this process. The information below focuses on the photographic formats most commonly found in research libraries and archives, namely black-and-white silver prints, glass plate and film base negatives, color chromogenic dye photographs (including negatives, prints, and transparencies), and digital output or hardcopy: ink jet prints, dye sublimation prints, and electrostatic prints.

Structure of Photographs

Photographs are composite objects. Since the advent of photography, many different materials have been used to make a wide variety of photographic materials.

A typical photograph consists of three different components:

۱/ Support

The support layer may be glass, plastic film, paper, or resin-coated paper.

۲/ Binder

The emulsion or binder layer, most commonly gelatin, but also albumen or collodion, holds the final image material or image-forming substance to the support. Papers for ink jet prints are often coated with synthetic materials.

۳/ Final image material

The final image material, made of silver, color dyes, or pigment particles, is usually suspended in the emulsion or binder layer.

Identification

Identification of various types of photographs requires a basic knowledge of the history of photographic processes. Curators and archivists charged with responsibility for photographic collections must be at least somewhat familiar with the various photographic processes and know when they were used. This information is needed not only for cataloging but also for making informed preservation decisions. Processes must be identified in order to distinguish between later copies and vintage originals. In addition, storage needs may differ with types of photographic materials. Photographs that are hazardous (such as cellulose nitrate), or may give off harmful gases as they deteriorate (such as nitrate and acetate negatives), or damage other materials (such as nitrate, acetate, and diazo) must be stored separately. The ability to identify photographic processes is also a prerequisite for selecting appropriate storage environments and storage enclosures for photographs. For example, acetate and nitrate film negatives should be stored in individual buffered paper sleeves because plastic enclosures trap harmful offgassing from the film base, which further accelerates deterioration of the image and film. Many excellent books devoted to photographic processes are available (Coe and Booth ۱۹۸۳, Reilly, ۱۹۸۳, Jarry ۱۹۹۶, Juergens ۱۹۹۹).

Some Common Photographic Processes
When they Were Introduced
and When they Were Most Popular?

۱۸۳۹-۱۸۶۰: daguerreotypes;
۱۸۳۹-۱۸۶۰: salted paper prints;
۱۸۵۱-۱۹۲۵: glass plate negatives (general);
۱۸۵۱-۱۸۸۵: collodion wet plate glass negatives;
۱۸۷۸-۱۹۲۵: gelatin dry plate glass negatives;
۱۸۸۹-۱۹۵۱: nitrate negatives (introduced by Kodak; ceased production in ۱۹۵۱; dates of production outside the United States vary);
۱۸۵۰-۱۸۸۰: albumen prints;
۱۸۸۵-۱۹۰۵: gelatin and collodion printed-out photographic prints;
۱۸۸۰: black-and-white gelatin developed-out photographic prints;
۱۹۳۴: acetate negatives introduced for sheet film;
۱۹۳۵: chromogenic color film and transparencies (introduced by Kodak; Kodachrome was the first process);
۱۹۴۸: instant black-and-white process (introduced by Polaroid; sepia first, then black-and-white in ۱۹۵۰);
۱۹۶۰: polyester film introduced;
۱۹۶۳: instant color print process (introduced by Polaroid; Polacolor was the first process; SX ۷۰ was introduced in ۱۹۷۲ and Polacolor ۲ in ۱۹۷۵);
۱۹۸۵: electrostatic, ink jet, and dye sublimation prints become increasingly used for printing photographic images.

Collection Management

Collection management includes four basic components: inventory, appraisal, cataloging, and proper housing and storage. Inventory is needed to determine which photographic processes are represented in the collection and which prints are mounted, unmounted, or in albums. Appraisal of the collection entails evaluation based on value, appropriateness of the collection to the mission of the institution, and an assessment of housing and preservation needs. Cataloging and arrangement involves identifying each item or collection, dating it, and assigning an accession number.

Materials in the collection, as well as all incoming materials, should be screened systematically during the inventory and appraisal steps in order to identify items with special preservation problems that require conservation treatment or stabilization until treatment can be obtained. Such actions may include protective boxing or stiff card supports underneath brittle or broken photographs.
The main problems to look for are:
a/ inherent problems affecting the structure of the print, such as extreme fragility, flaking binder layers, or other physical damage;
b/ external problems, such as active mold, insect infestation, or the use of inappropriate pressure-sensitive tape or rubber cement adhesives.

Catalog records should be prepared for each item in the collection that state the nature of the object, its physical description, and an evaluation of its condition. Where large numbers of similar materials are concerned, a finding list containing general or characteristic information may suffice in lieu of individual item records. Cataloging and access tools can support preservation by minimizing the need for researchers to handle original photographs or one-of-a-kind images, including negatives for which no reference copy exists. If good cataloging and access tools are provided, the need for researchers to browse through originals is reduced.
Some examples of access tools are:
a/ digitized images accessed on a computer;
b/ a small ۳۵mm copy photo contact print of the original attached to a catalog card;
c/ photographs reproduced on microfilm or microfiche;
d/ photocopies (black-and-white or color) of originals.

Once the collection has been inventoried, appraised, cataloged, and arranged to library and archives standards, certain photographic materials (such as cellulose nitrate and cellulose acetate film base materials, and chromogenic dye photographs) should be housed and stored separately if possible. By isolating these photographs, these items may be stored in colder and drier environments that will maximize their lifespan. In addition, segregation of some photographic materials, such as deteriorating film base materials, reduces the risk of damage caused by acidic offgasing that can damage other photographs stored nearby. Lastly, fire safety codes may require separate storage for cellulose nitrate materials (NFPA ۴۰). However the nature of many collections does not allow for separation of different materials and a compromise frequently must be made between the conflicting needs of the photographs in the collection. High-quality reproductions should be made for items that are too deteriorated to be handled without damage. Once a deteriorated original is duplicated or reproduced it may be withdrawn from service to researchers. Increasingly digitization projects are providing these types of surrogates.

Comprehensive collection management includes proper maintenance of and storage for the collection. Protective housings can minimize handling damage and wear and tear. A proper storage environment is the best defense against deterioration, since harmful chemical gases, high temperature, and improper relative humidity levels affect photographs.

Deterioration

Four principal factors contribute to the deterioration of photographs: poor environmental storage conditions, poor storage enclosures, rough or inappropriate handling that results in unnecessary wear and tear and shelving conditions, and in some cases, the presence of residual photographic processing chemicals or the use of exhausted processing chemicals.

۱/ *Environmental Factors*

The environmental factors that affect the preservation of photographic materials are relative humidity and temperature, air pollution, light, and housekeeping practices.

۱/۱ *Relative Humidity and Temperature*

All photographic materials are sensitive to high, low, and fluctuating relative humidity (RH), which is a measure of how saturated the air is with moisture. High RH affects all components of photographs. High RH causes a gelatin binder to become soft and sticky, making it vulnerable to mechanical damage and image deterioration. Low RH causes the binder to shrink and crack and the secondary support to curl.

High temperature speeds up the rate of deterioration. The higher the temperature, the faster a photograph deteriorates, especially at high RH levels. High humidity and temperature, combined with the damaging effects of air pollution, are especially damaging and cause silver images and many color dyes to fade and discolor. Adverse environments can also cause paper to yellow and become brittle, especially if the paper is acidic.

High temperature and high humidity conditions may contribute to the growth of microscopic mold spores on the image-containing layer and on primary and secondary paper supports. Once active mold infests photographic materials it is usually impossible to remove without damaging the photograph. Mold tends to grow when the RH is greater than ۶۰% and the temperature is above ۷۵-۸۰° F. Of course mold may grow at much lower temperatures – even in a damp refrigerator!

Temperature and RH fluctuations, or "cycling", result in chemical and mechanical changes that are especially damaging to photographs. Cycling promotes the movement of moisture in and out of a photograph, speeds up the rate of chemical deterioration of primary and secondary supports, and promotes the breakdown of the binder that holds the final image material to the support. When both humidity and temperature are high, or when materials undergo temperature and RH cycling, structural damage and the rate of chemical deterioration are greatest.

The ideal RH for storage of a mixed collection containing historical photographic prints, slides, and negatives is a set point between ۳۰% and ۵۰% without cycling more than +/- ۵% a day. If only photographs are stored in a given area, ۳۰-۴۰% RH is best. If photographs are stored with paper, parchment, or leather materials, it may be necessary to maintain ۴۰-۵۰% RH to avoid placing unwanted stress on non-photographic materials. However, some materials, such as negative films and transparency films (nitrate and acetate plastic) and some historic glass plate negatives, will deteriorate further at ۴۰-۵۰% RH. The deterioration of acetate and nitrate is strongly dependent on RH even at moderate levels of ۴۰-۵۰%. Recent changes in International Organization for Standardization (ISO) specifications recommend several different climates that can achieve the same projected life expectancy for film base and chromogenic dye photographs. These climate options are based on the concept that temperature and RH have a synergistic effect on each other – within certain ranges, a lower temperature can compensate for a higher RH and vice versa. For example, at cool temperatures (۷°C), the RH range is ۲۰-۳۰%, while colder temperatures allow for a broader range between ۲۰-۴۰% at -۳°C or even ۲۰-۵۰% at -۱۰°C (ISO ۱۸۹۱۱). Recent research indicates that historic nitrate film also benefits from these same storage conditions (Reilly ۱۹۹۳). Glass plate negatives should be stored at ۳۰-۴۰% RH to minimize glass decomposition and flaking (ISO ۱۸۹۱۸). Ink jet prints, especially those from the early and mid ۱۹۹۰s can be particularly sensitive to high levels of humidity. Significant damage may occur with some processes by humidity above ۸۰%. As with other photographs, relative humidities above ۵۰% should be avoided when storing ink jet prints.

Storage temperatures should be kept as low as possible but high enough to allow reasonably comfortable working conditions for staff. The highest recommended "extended-term" storage temperature for black- and-white prints and negatives on polyester film base is ۱۸°C. ISO defines "extended-term" as *when it is desired to preserve information for as long as possible* (ISO ۱۸۹۲۰). Daily fluctuations greater than +/-۲°C should be avoided. Cellulose nitrate, cellulose acetate, and chromogenic dye photographs deteriorate rapidly in at ۱۸°C and require cool (۱۰-۱۶°C), cold (۲- ۸°C), or freezing (<۰°C) conditions for extended-term storage (ISO ۱۸۹۲۰). Generally, the colder the storage the better, if relative humidity is also low (۳۰-۵۰%).

When choosing a cold storage system, keep in mind that cold storage units are expensive to maintain, especially units for lower temperatures. Household refrigerators and freezers may present low cost options for small collections of materials that benefit from cold storage, but these require special vapor-proof packaging. Caution must be exercised when using any cold storage system to avoid elevated RH or water condensation. Contingency plans must be made to protect photographs from potential damage caused by condensation if the refrigerator or vault ceases to operate due to a mechanical failure or power outage. Cool or cold storage systems can delay access to the collections because the photographs must equilibrate to ambient temperature and RH before they are used in order to avoid moisture condensation. While this delay may be inconvenient it is crucial to understand that only cold storage can provide long-term access to these materials. Without cold storage, temperature-sensitive materials will deteriorate in a matter of a few decades; with cold storage they can remain unchanged for many centuries.

۲/۷ Air Pollution

Air pollution attacks photographs in the form of:
a/ oxidant gases,
b/ particulate matter,
c/ acidic and sulfiding gases,
d/ environmental fumes.

Oxidant gases are composed primarily of pollution created by burning fossil fuels such as coal and oil. Nitrogen oxides (oxide and dioxide) and ozone are the two main gases that threaten photographic images. Nitrogen oxides are produced by combustion, as in automobile engines. Ozone occurs naturally in the upper atmosphere, but can be formed in the lower atmosphere when sunlight interacts with nitrogen oxide. Ozone is also produced by some electrostatic copiers and printers. Oxidant gases cause photographic images to fade by chemically interacting with the final image material. Silver photographs and some ink jet prints are both especially sensitive to pollutants.

Particulate matter, such as soot and ash particles from manufacturing processes, exists in abundance outdoors and can enter the library or archives through heating and cooling ducts, doors, and windows. Particulates, which may be greasy, abrasive, and chemically or biologically active, settle on shelves and on collection materials and create dust that is spread to other materials when they are handled.

The by-products of combustion combined with moisture in the atmosphere pose another risk to photographic materials. When fossil fuels such as coal and oil are burned, nitrogen and sulfur dioxide are produced. The reaction of nitrogen and sulfur dioxide with water in the atmosphere produces nitric and sulfuric acids. These acids attack all components of photographs and cause silver images to fade and paper and board supports to discolor and become brittle.

Environmental fumes can be especially damaging to photographic images even in small quantities. Peroxides from untreated wood, paints, and varnishes; poor quality paper or plastic products in close proximity to photos; and the fumes from common cleaning solvents can cause images to oxidize and fade.

Air entering the storage area should be filtered and purified to remove particulate and gaseous matter. A well-designed filtration system includes cellulose or fiberglass filters that remove particulate matter, and chemical absorption system that filters out gaseous pollutants. Air filters must be changed regularly to be effective. Air circulation should also be checked periodically. There should be no stagnant air pockets, or drafts that bring unfiltered outside air into storage areas. Storage cabinets, enclosures, and boxes may provide some protection from pollutants and harmful gases. Many photocopiers and printers emit ozone, which is damaging to photographs, so their use near collection storage areas should be avoided. Do not permit unsupervised cleaning or painting of storage areas. Do not allow unknown cleaning materials or those containing chlorine and other bleaches, oil- based paints, or varnishes to be stored or used near photographic materials. Avoid storing photographs in freshly painted rooms since paint vapors can interact with image materials causing them to fade. Detergents and soaps without chlorine are recommended for cleaning storage areas. Use only water-based latex paints to paint photographic storage areas. Ideally, latex-painted display cases or storage areas should be allowed to dry for at least a week before use with photographs. When ordering metal furniture, specify a powder-coated finish.

۴/ Light

Permanent display of photographs is not recommended; most photographic materials are vulnerable in varying degrees to deterioration caused by light. Periodic changing of photographs on display is an excellent way to minimize light damage to photographs. For photographs that are especially sensitive to damage from light, the best policy is to display a facsimile. Damage caused by light is cumulative and depends on the intensity, length of exposure, and the wavelength of the radiation. Visible light in blue part of the spectrum (۴۰۰ to ۵۰۰ nanometers), and ultraviolet (UV) radiation (۳۰۰-to ۴۰۰ nanometer region) are especially damaging. Sunlight and standard fluorescent light are both strong sources of UV.

Light levels in exhibits should be kept as low as possible, but high enough to allow for viewing and should be in the range of ۳۰-۱۰۰ lux. Currently, it is very difficult to determine the proper light levels for ink jet prints because of the varying light sensitivity of different types of ink jet systems. Some pigment-based systems are fairly insensitive while some dye systems (especially those used in the early to mid ۱۹۹۰s) are extremely sensitive to light. Without knowing the exact composition of an ink jet print it is recommended to keep light levels in the ۳۰-۱۰۰ lux range and to limit the duration of display. Color slides are particularly susceptible to fading when exposed to both visible and UV light. For example, Kodachrome slides can fade significantly within ۱۰ minutes of projection, although Kodachrome has excellent color stability in dark storage. Ultraviolet light levels should not exceed ۷۵ microwatts per lumen. A UV meter is required to measure ultraviolet light levels; incandescent light levels can be measured with a photometer or even a camera light meter (Canadian Conservation Institute, N۲/۵). Sources do exist for setting exhibition policies (Wagner ۲۰۰۱, Watkins, forthcoming).

Reading room lights should be kept at a comfortable viewing brightness. Windows and fluorescent lights in reading rooms and storage areas are often chief sources of damaging ultraviolet light. The installation of low-UV-emitting bulbs or UV-absorbing fluorescent bulb sleeves can help eliminate this problem. UV filtering window glazing or the installation of window shades may also help. Low-UV-emitting bulbs and sleeves are available from several manufacturers. Light levels in storage areas can also be controlled by the use of timed shut-off switches. Dark cloths or sheets of folder stock (heavyweight paper) or mat board should be available in reading rooms for covering objects when not in use by readers. Photographs should be covered if they are not immediately returned to storage after use, or while an exhibition is being installed.

Housekeeping

Insects (silverfish, cockroaches, beetles) and rodents (rats, mice, and squirrels) are all attracted to photographic materials. In addition to eating materials, they also foul the storage area and materials with their droppings. They make nests that can be difficult to locate and remove. A good policy is to prohibit eating or drinking where collections are stored. Floors, shelves, boxes, and cabinets should be dusted or vacuumed, or both, on a regular basis. Collection materials should never be stored on the floor where they are more likely to be damaged by insects and rodents or water leaks.

Chemical Processing and Image Stability

Major silver deterioration occurs when photographs are not correctly processed and washed, that is, when exhausted fixer is used, when photographs are not fixed for a sufficient time, or when washing is inadequate. Improper washing fails to rinse residual thiosulfate complexes (fixer) from the film or paper. Over time, residual fixer left in the photograph causes the image, binder, and support to turn yellow or brown and the silver image to fade. High temperature and humidity speed this process. Photographs that were not well fixed remain light sensitive and may darken when exposed to light. Damage from residual chemicals occurs with time and can go unnoticed for years. The stability of chromogenic photographs also can suffer from improper processing. To prevent this type of damage insist that all photographic chemical processing and development be done to ISO standards (ISO ۱۸۹۰۱), especially when duplicating negatives, making reference prints from collection negatives, and if feasible, when acquiring new photographs from photographers. Use of chemical toners also helps to protect silver images from deterioration. Color processing should conform to manufacturers' recommendations for the particular type of paper or film.

Storage Systems and Enclosures

Proper storage furniture and enclosures for photographic materials are important preventive measures that protect items from physical damage, stabilize delicate or fragile materials, and provide basic care for all materials in the collection. Storage cabinetry and enclosures must be chosen and used carefully, however, so that they do not contribute to the deterioration of collection materials. A number of factors influence storage decisions – condition of the photographs in question, frequency of use, space, environmental conditions, and staff and financial resources available. Often only incremental improvements can be made when working with large collections – but these can have a dramatic impact over the long term.

Photographic materials can be seriously damaged if stored in cabinets made of inferior materials that offgas harmful chemicals or that do not provide adequate physical protection. Damage is also caused when photographs are stored loosely in oversized containers or too tightly in overstuffed drawers. Prints stored loosely in a file drawer will slump and curl, for example, and be vulnerable to damage each time the drawer is opened and items are handled. Glass plate negatives are especially fragile and will break when crowded into file cabinets unprotected or stacked on top of one another.

Storage furniture, including cabinets and shelves, should be made of non-combustible, non-corrosive materials such as stainless steel, anodized aluminium, or steel with a powder-coated finish. Shelves made of wood and wood by-products should generally be avoided since they contain lignin, peroxides, and oils that can offgas or migrate to photographic materials. New baked enamel shelving units may offgas harmful chemicals since the paint is very difficult to properly cure during manufacture.

Prints, negatives, and slides can be damaged by enclosures that are poorly designed or are made of inferior materials. Acidic chemical agents from poor quality materials can migrate to photographs and destroy the images they were meant to protect. Poorly designed enclosures can produce the same result.

۱/ Materials

Many commercially available enclosures are labeled "archival" or "acid-free". However, some of these same items may contain lignin, dyes, sizing agents, coatings, plasticizers, or other harmful additives. Never use enclosures made from unprocessed woodpulp paper, glassine, or polyvinyl chloride (PVC) to house or store photographs. Avoid products made from colored papers because they often contain dyes or inks that are unstable and will migrate or bleed onto photographs or otherwise adversely affect the photographs stored within. For an enclosure material to be completely safe it must meet or exceed the specifications in the latest revision of ISO ۱۸۹۰۲ including the Photographic Activity Test (PAT) ISO ۱۸۹۱۶. Purchase enclosure materials from a reputable supplier.

۲/ Design

Paper envelopes are often used to store prints and negatives. Since the adhesives used to seal envelopes may cause staining and fading of the silver image, the emulsion (or image) side of a print or negative should be placed away from the seam. In this way the risk of staining or fading of the front is minimized. When envelopes with seams are used, the seams should run along the sides of the envelope rather than down the center. A good approach to housing photographs is to provide several layers of protection by first placing photographs into sleeves or envelopes, then into folders, and finally into document storage boxes. This procedure may not be feasible in every institution or with every type of collection. In some cases, grouping photographs into folders and then into storage boxes may suffice.

۲/ Paper or Plastic?

The choice between paper or plastic enclosures is a good example of how to weigh the various factors involved in making housing decisions. As described above this decision includes the type of photographs to be housed and their condition, the anticipated amount of use the materials will receive, available space, financial resources, and environmental storage conditions. Paper enclosures usually cost less than plastic, but items that are used frequently can be abraded by repeated removal from and insertion into paper enclosures. Paper sleeves and envelopes should be made according to ISO specifications, which recommend that the paper have an alpha cellulose content of ۸۷% and contain no lignin, groundwood, or alum-rosin sizing. The paper should be buffered to a pH of ۷-۹.۵. Buffered paper may be used for acetate and nitrate films, platinum prints, silver prints, chromogenic prints, and prints mounted on acidic boards. Unbuffered paper (tending to have a pH of ۶-۷) is recommended for cyanotypes and architectural drawings (Kissel and Vigneau ۱۹۹۹, Ware ۱۹۹۹).

Plastic enclosures are preferred for frequently used collections because they protect photographs from fingerprints and provide physical support. Plastic enclosures should be made from plastics such as polyester, polyethylene, polypropylene, spun-bonded polyolefins, or polystyrene. These plastics are recommended by ISO standards because they are typically inert, unplasticized, and have good chemical stability. They may be used safely with many photographic materials in many situations. Since photographs can adhere to smooth surfaces at high humidites, use of plastic of any type should be avoided if prolonged storage at relative humidities above ۸۰% is likely. Avoid all plastics that have fillers, coatings, or UV absorbers. Avoid the use of polyester, polyethylene, and polypropylene that has a hazy film on the surface, which indicates that the plastic film is coated or is heavily plasticized. Avoid using adhesives or fasteners that may cause chemical or physical damage, such as rubber cement, pressure-sensitive tape, paper clips, or rubber bands. When not stored in cold conditions, plastic enclosures of any kind should not be used with nitrate or early acetate films.

۲/ Suggested Storage Methods

۴.۱ Prints

An excellent storage method for photographs is to place the print in a mat. Mats provide a great deal of protection from physical damage and also provide some degree of protection from pollutants and environmental fluctuations. However, mats are fairly expensive, time consuming to make, and greatly increase the amount of storage space needed for a large photograph collection. For many situations a paper folder or a polyester "L" sleeve with a piece of ۲-ply board for support can be good solutions when a mat is not a feasible option. A polyester "L" sleeve is made from two pieces of polyester placed on top of one another and sealed along two adjacent edges. Place the sleeved photograph into a buffered pH folder and into a document box. An even less costly approach for large collections or collections that receive little use is to place the photograph into an "L" sleeve or a folder and use the ۲-ply support only for brittle items. This choice does however decrease the degree of protection from handling damage. Photographs with flaking or especially sensitive surfaces should not be stored in plastic because damage that can occur from the static charge lifting media or binders off the photographic support. Prints larger than ۸ x ۱۰ inches should be shelved horizontally. If vertical storage is chosen, be sure the box is snugly filled, or use a spacer to fill unused space to prevent photographs in the box from slumping. If vertical shelving is chosen, make certain the document box is well supported on the shelf.

۴.۲ Oversized prints

Place oversized prints in a folder, interleave with paper, or sleeve in polyester as above. The housed photographs should then be stored in a large document box on shelves or in map storage drawers. Rolling of photographs should be avoided since the photograph may crack when it is unrolled for use.

۴.۳ Framed photos

If storage for framed items (such as a rack or padded bin) is available, framed photographs should be protected from light exposure with dark cloth coverings or other opaque materials. If the photograph is stored framed, check that the matting and hinging / attachment is appropriate and of high quality materials. If there is no appropriate storage for framed items, remove the photograph from the frame and store as above.

۴.۴ Glass plate negatives

Intact glass plates may be stored individually, in seamed or seamless paper enclosures. The plates should then be arranged vertically on their long edges in cabinets or in document storage boxes on open shelving. Seamless sleeves are best for low-use negatives, such as those that have been retired from darkroom use. Shelving with adequate strength is needed to hold the weight of the glass plate negatives. Boxes should be clearly labeled "fragile/glass" and "heavy". Filler ۲-ply board or corrugated board should be used to fill out partially filled boxes to minimize jostling of plates during handling. Glass plates larger than ۵ x ۷ inches are ideally stored in cabinets with rigid metal dividers spaced every ۱ to ۱ ۱/۲ inches.

۴.۵ Broken glass plates, or those with deteriorated image layers

Damaged plates may be stored in sink mats constructed to guidelines suggested by McCabe (۱۹۹۱) with materials that meet the ISO PAT test. Another less elegant solution is to store broken or cracked glass plates between good quality ۴-ply or corrugated board inside a ۴-flap enclosure. These can then be stored flat in a shallow box. Plates larger than ۸ x ۱۰ should be stacked only two deep due to their weight. Cracked plates should be supported with a piece of glass or lignin-free ragboard inside their envelopes or sleeves. Ideally, the storage and stabilization of damaged glass plate negatives should be done with the consultation of a conservator. A photograph conservator should perform repair of a broken plate.

۴.۶ Cellulose nitrate negatives

Cellulose nitrate film was manufactured between ۱۸۸۹ and ۱۹۵۱ in the United States. It was produced into the ۱۹۶۰s in other countries. Eastman Kodak was the first company to successfully mass-produce nitrate film, but it was also manufactured by other companies worldwide. Cellulose nitrate is flammable and should be stored, transported, and disposed of following appropriate codes and regulations (NFPA ۴۰). Nitrate film is inherently unstable and becomes acidic, sticky, and brittle with age. Cellulose nitrate deteriorates in stages, beginning with a breakdown of the cellulose nitrate plastic support. As nitrate deteriorates it poses a threat to other types of photographs stored in the area by emitting oxides of nitrogen, which attack the silver image, the gelatin binder, and eventually the support base of other papers and films. Nitrate materials should be identified, accurately duplicated if possible, housed in buffered paper enclosures (never plastic), and stored away from other collection materials in a well-ventilated room (Eastman Kodak ۱۹۹۸). All nitrate films should be inspected periodically for signs of deterioration. Cellulose nitrate in poor condition can auto-ignite at temperatures as low as ۴۱°C. Fire codes require that the nitrate materials be stored separately in fireproof cabinets, in vaults, or offsite. Storage at low temperature and low RH greatly slows the deterioration of nitrate film.

۴.۷ Cellulose acetate negatives

Starting in the ۱۹۲۰s cellulose nitrate base film was gradually replaced by film known as "safety” or cellulose acetate film. Cellulose acetate films (cellulose diacetate, cellulose acetate propionate, cellulose acetate butyrate, or cellulose triacetate) tend to shrink when plasticizers and solvents introduced during manufacturing evaporate out over time and cause the film base to cockle and the gelatin emulsion layer to wrinkle as it delaminates from the film base. Eventually the image is distorted by the network of wrinkles or channels formed in the emulsion layer. In addition, the film base becomes increasingly acidic and decomposes. The smell of acetic acid is a sign that the cellulose acetate film base itself is deteriorating and that damage is occurring. Triacetate film, introduced in ۱۹۴۸, remains in wide use today. All acetate films should be inspected periodically for signs of deterioration. Deteriorated items should be stored in buffered paper sleeves, under very stable environmental conditions. Unstable, early acetate negatives should be stored separately from prints in a well-ventilated storage room. Plastic enclosures may be used for recently produced safety film negatives (acetate or polyester) that are expected to receive use. Long-term storage of acetate materials should be in buffered paper enclosures. Storage at low temperature and low RH greatly slows the deterioration of acetate film.

۴.۸ Chromogenic Dye Photographs
Chromogenic dyes are inherently unstable and will fade when exposed to light. They will also fade and yellow in the dark even at "normal" temperature and relative humidity levels. In general, high temperatures speed the rate of color fading. Chromogenic photographs should be stored at ۲°C and ۲۰-۵۰% RH, which will slow color fading and image loss.

۴.۹ Albums, scrapbooks, and mounted photographs
Historical print mountings were often made of acidic, unstable materials. Many over-the-counter adhesives used to mount photographs into albums and scrapbooks are acidic and will eventually discolor, become brittle, and damage materials. When acidic paper mounts become brittle, the photographic image itself is at risk because of breakage. Mounted photographs that are fragile or brittle may be stabilized with a rigid support such as ۴-ply matboard inside a protective enclosure or by placement into a sink mat for protection.

Albums can be wrapped in paper and placed in a document box or in a fitted protective enclosure. Albums may be given full conservation treatment, especially if they are particularly valuable; unfortunately, this is the exception rather than the rule, due to the high cost of album conservation. Heavily used albums or scrapbooks should be photographically reproduced for research use. Interleaving should be done judiciously because it adds bulk to an album and places undesirable stress on the binding. Examples where album pages may benefit from the protection provided by interleaving include the following: photographs that are highly glossy or easily abraded, or both; photographs that have fixer stains; platinum prints; and photographs with tape or adhesive applied in such a way that it may come in contact with other items in the album.

Digital Output or Hardcopy
In the past twenty years an enormous number of new processes and products have been introduced in the digital printing field. Within the larger field of digital output, ink jet, electrostatic and dye sublimation prints are becoming increasingly used to make works of art, photographs, and other documents that are collected and cared for by libraries, archives, museums, and private collectors.

These materials differ significantly from traditional photographic processes. These differences may impact storage and exhibition practice for each process. Since these materials are relatively new, we are only beginning to experience how they will age and possibly deteriorate over time. Currently storage and testing standards for these materials are being incorporated into ISO standards concerning imaging materials.

۱/ Ink Jet Prints
An ink jet printer deposits tiny ink droplets on a support of some kind, such as paper or plastic. Inks can be made with organic dyes or, increasingly, pigments. An ink jet printer can print onto a large variety of supports and may use various ink sets. These factors result in an extremely large number of printer / ink set / support combinations. Research has shown that the same ink set printed by the same printer on different supports can have dramatically different stabilities (Wilhelm ۲۰۰۲). This ink / support interaction demonstrates the importance of knowing as much as possible about the specific ink set / paper combination not only when making prints but also when making acquisition, conservation and preservation decisions. Emerging concerns with ink jet prints include dark stability, light fading, sensitivity to moisture, and sensitivity to pollutants such as ozone.

As ink jet materials have become used for works of art and other objects of long-term value, the digital printing industry has made great strides in lightfastness of ink systems. However, these materials as a group should not be considered completely lightfast and caution should be used when displaying them. Moisture sensitivity is another area of concern. Many ink jet prints have been found to be sensitive to water and smudges. Image losses may result from brief exposures of water and even high levels of relatively humidity over very small amounts of time. With use of new organic dyes and pigments, water fastness has improved. The effect of pollutants, such as ozone, on ink jet prints is an area of growing concern. Testing methods for gas-fading are being developed as ISO standards.

Electrostatic Prints

Electrostatic technology has been used in office copiers since ۱۹۵۹. The addition of a laser to the system allows for printing of digital information. During the last twenty years color electrostatic systems have become common. Increasingly, computer printers and copiers using electrostatic technology are being used to produce not only textual documents but also black-and-white and color photographs as digital file output. In these systems, toner containing resin and pigment is fused to paper with heat. At this time, these materials are generally of lesser image quality than ink jet and dye sublimation prints and are used less frequently for producing works of art. However, these systems are less sensitive to water and pollutants, due to the nature of the pigments and resins that can be used. Since some of the pigments in these systems are somewhat unstable, caution should be used in exhibition. Also, many office papers are of poor quality and may discolor upon long-term exposure to light.

Dye Sublimation Prints

Dye sublimation prints use a thermal transfer process to create images using dyes that are made gaseous (a sublimation process) and then condensed onto a receiving layer. Typically the receiver is a paper with a coating that is specifically designed to receive the dyes. Thus, unlike ink jet and electrostatic prints, there are considerably fewer types of papers and colorant systems used within this group of material. As with all materials made up of organic dyes, light exposure should be minimized since organic dyes can fade under these conditions. This technology is relatively expensive compared to ink jet and electrostatic printing and is not as common as those printing methods.

Handling

The risk of damage to materials is increased when researchers and staff who are responsible for photographic materials are not trained in the proper care and handling of those materials. Ignorance, neglect, and carelessness account for a significant percentage of damage to photographs. Repair of photos with pressure-sensitive tape, marking original prints with ink or felt-tip pens, and exhibition of materials under inappropriate conditions are examples of negligence. Neglect also includes the lack of a disaster response plan, inadequate security precautions, and poor collection management procedures that require valuable originals to be handled repeatedly. Carelessness includes rough handling during cataloging, housing, and viewing; storage in a hazardous location; and damage to materials as a result of inadequate transport systems.

When handling photographs and negatives, be sure that hands are freshly washed, wear clean lint-free cotton gloves or inert plastic gloves (such as nitrile), and avoid touching the photograph surface. If a photograph must be moved a short distance or turned over during examination, use an auxiliary support (such as a piece of Plexiglas, ۲- or ۴-ply rag board, or folder stock) to protect the item from damage caused by unnecessary touching, bending, and flexing. Use a stable, appropriately sized book cart with horizontal shelves to transfer materials between storage and research areas. Provide book cradles in research areas that allow photograph albums to be viewed safely. Cradles permit a tightly bound book to be opened enough to be read but not so far that it is damaged. Felt covered "snakes" filled with sand can be used to hold pages open as long as they do not touch the surface of photographs.

Train staff to arrange, describe, and rehouse photographs with care. Instruct them in the proper method for handling films, glass plates, and prints, as well as brittle, broken, or flaking photographs of all types. Provide adequate storage enclosures and other necessary supplies during housing and cataloging so that materials will be housed properly. Evaluate training procedures on a regular basis and revise them as needed.

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