HARRISON MEMORIAL LIBRARY BOARD OF TRUSTEES

STAFF REPORT

May 27, 2015

To: HARRISON MEMORIAL LIBRARY BOARD OF TRUSTEES
From: ASHLEE WRIGHT, LOCAL HISTORY LIBRARIAN
Subject: RECEIVE A PRESERVATION SURVEY OF PHOTOGRAPHIC MATERIALS FOR THE ARTHUR MCEWEN COLLECTION CREATED BY GAWAIN WEAVER, ART CONSERVATOR

Recommendation: Receive a preservation survey of photographic materials for the Arthur McEwen Collection created by Gawain Weaver, Art Conservator.

Summary: The Arthur McEwen Collection, made up of over 7,000 cellulose acetate based photographic negatives, is currently in a state of serious deterioration. After a survey of the collection, art conservator Gawain Weaver has recommended that the negatives be scanned and placed in cold storage permanently (Attachment A).

Discussion: Arthur McEwen was a Carmel-based free-lance photographer who was active on the Monterey Peninsula starting in the 1950's and through the 1990's. His photographs appeared in the Monterey Herald and Game and Gossip among others, and feature scenes and happenings in Carmel, Monterey, and Pacific Grove, as well as family portraits.

The McEwen collection is made up of over 7,000 cellulose acetate based negatives, housed in 10 boxes. Within the boxes are paper sleeves, which house the negatives, as well as typewritten copy and the corresponding newspaper clipping. The sleeves in each box are in order by date, and are labeled with the subject and photo number assigned by McEwen. Prior to being donated to the Local History Department the 10 boxes were stored in a garage, and subject to temperature fluctuations and the damp. Because it was clearly evident that the negatives were in a state of deterioration at the time of the donation, the negatives have been stored in the back workroom of the Local History Department, in quarantine from the other negative collections and photographs housed in the vault. I began to research cellulose acetate negatives: how to preserve them, restore them and digitize them. My research led me to Gawain Weaver, an art conservator and expert in dealing with photographs and negatives.

At my request, Weaver did a survey of the McEwen Collection on April 23, 2015, as well as the other negative collections housed in the vault. The negative collections housed in the vault are in excellent condition and being stored properly.

The McEwen collection, however, is in a serious state of deterioration, especially the earlier years, which are in the worst condition. He recommends placing the negatives into cold storage as soon as possible. They can either be scanned prior to this, or removed from cold storage as necessary to perform the scanning. Weaver's report also makes recommendations for a 20.2 cubic foot upright freezer, and temperature and humidity monitoring equipment.

I have reviewed both of his recommendations and am currently working on a work plan to begin scanning the still scannable negatives. With the start of the new fiscal year a freezer, the appropriate monitoring equipment, and other supplies needed, will be purchased. The freezer will be housed in the Local History Department.

Harrison Memorial Library

Preservation Survey of Photographic Materials

March 2015

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Introduction

This report is the result of a 1-day survey of the photographic materials at the Harrison Memorial Library conducted by photograph conservator Gawain Weaver on May 23, 2014. I was assisted in this survey by local history librarian Ashlee Wright who showed me the collections and explained the history of their care. The focus of this survey is the Arthur McEwen negative collection, though other film materials in the library were also examined. The preservation needs for the materials are given after a physical description for each collection. The appendices provide some basic reference literature specific to the preservation needs of this collection.

McEwen Negative Collection

10 negative storage boxes

The 10 storage boxes that house the McEwen negative collection are each 6" x 6" x 21". They are organized by date and by the original studio numbered sleeves, Boxes 1-8 dating from 1951-1963, and Boxes A and B from 1952-1990.

Within each box all of the contents are kept in 4"x5" paper film sleeves. Generally, each paper sleeve contains all photographic film, notes, and published clippings from a single photo shoot. A measurement was made in linear inches of the material in each box. This measurement was done while lightly compressing the film sleeves. 7000 is a conservative estimate of the total number of negatives, since it is based on a sampling from Box 1 of mostly thicker 4x5 negatives, and McEwen shifted toward smaller formats and thinner negatives over the course of his career.

McEwen is shooting only sheet film in 4x5 and 2¼ x 3¼ format when the collection begins in the early 1950s. By 1954 he is occasionally using 35mm roll film and by 1956 medium format roll film. By 1957 he is primarily shooting medium format. The state of deterioration of the film varies mostly with date, the earliest film being in much worse condition than later film. All of the film appears to be cellulose acetate based.

Box 1 February 1951-July 1952

17" of 4x5 paper film sleeves with 4x5 and 2¼ x 3¼ sheet film. Mostly B+W with only a few color transparencies.

Based on a count of 5" of the material, there are approximately 700 negatives in Box 1.

CONDITION: All the negatives are already channeled or in an advanced state of deterioration and will become channeled and physically distorted in the near future.

Box 2 July 22, 1952-February 11, 1954

17" of 4x5 paper film sleeves with 4x5 and 2¼ x 3¼ sheet film

More 2¼ x 3¼ format sheet film than in Box 1. Mostly B+W with only a few color transparencies.

CONDITION: All the negatives are already channeled or in an advanced state of deterioration and will become channeled and physically distorted in the near future.

Box 3 February 26, 1954-December 28, 1955

17"(compressed) of 4x5 paper film sleeves with 4x5 and 2¼ x 3¼ sheet film

still mostly 4x5 B+W with a little color and smaller sheet film. A few 35mm B+W negatives

CONDITION: All the negatives are already channeled or in an advanced state of deterioration and will become channeled and physically distorted in the near future.

Box 4 January 14, 1956-September 17, 1957

17"(compressed) of 4x5 paper film sleeves-- mix of 4x5 B+W, 35mm, and medium format. More color than previous boxes, but still mostly B+W.

CONDITION: All the film is deteriorating, but a higher % of the film compared to previous boxes is still in good enough condition to scan.

Box 5 September 22, 1957-January 31, 1960

17"(compressed) of 4x5 paper film sleeves with mostly 35mm and medium format. Some 4x5 B+W left. More color than previous boxes.

CONDITION: All the film is deteriorating, but a higher % of the film compared to previous boxes is still in good enough condition to scan.

Box 6 February 9, 1960-February 23, 1962

17" (compressed), mostly medium format B+W, a few color MF trannies, still lots of clippings in each sleeve.

CONDITION: All the film is deteriorating, but a higher % of the film compared to previous boxes is still in good enough condition to scan.

Box 7 February 26, 1962-November 18, 1963

15" (compressed), all medium format B+W, no channelling yet, still lots of clippings in each sleeve.

CONDITION: All the film is deteriorating, but most of the film is not channeled and is in good enough condition to scan.

Box 8 November 18, 1963-June 19, 1988

15" (compressed), all medium format B+W with 4 rolls of 16mm motion picture films.

CONDITION: All the film is deteriorating, but most of the film is not channeled and is in good enough condition to scan.

Box A April 4, 1952-September 12, 1960

20" (compressed), mostly deteriorated and channeled 4x5 B+W film, with some 35mm and medium format from the later 50s.

CONDITION: A mix of early film that is severely channeled and later film still in good enough condition to scan.

Box B September 13, 1960-February 27, 1990

19" (compressed), mostly medium format B+W film, 2 rolls of 16mm B+W motion picture film.

CONDITION: A few deteriorated 35mm film strips, but most of the negatives are in excellent condition.

Preservation Recommendations:

Many of the negatives in the McEwen collection have reached advanced stages of deterioration. They have become very acidic and are off gassing acetic acid and other more harmful volatile organic compounds that create a significant health risk for anyone around them. In addition, the deterioration is proceeding at a rapid rate and their condition will become progressively worse over time.

Fortunately, freezing the negatives is a relatively inexpensive method to slow down the deterioration and remove the health risk issues in the storage environment at the same time. The negative boxes will need to be double-bagged and prepared for freezing as outlined in the Appendix. They can then be placed in an upright freezer and the boxes can be removed as needed for scanning or other preservation needs.

Digitization of film that has not yet channeled can be done in-house on the library's Epson scanner. We can also provide an even higher-quality digitization of unchanneled medium format, 35mm, and 4x5 film using a Hasselblad Flextight virtual drum scanner. Prices vary from $2-$5 per image depending on quantity, format, and resolution.

Film with advanced deterioration and the distortion of the channeling can be fully restored by stripping the gelatin image layer from the deteriorated base. The image layer is then scanned, and dried under weight. The dry gelatin image layer can then be stored in a polyester sleeve in the main vault without any concern for further deterioration, since the deteriorating film base has been discarded. This process costs $60-$100 per image, depending on quantity and format. It may make sense to carefully select images from among those that are deteriorated for long-term preservation.

Additionally, there are 6 rolls of 16mm motion picture film, both Kodachrome and B+W in the McEwen collection. Freezing the motion picture film is the best option as this will allow it to be inexpensively preserved indefinitely. High-quality transfer to digital files for access can be done inexpensively by providers such as Movette in San Francisco (www.movettefilm.com).

Other Photographic Collections in the main vault

Glass plate negatives (Frank Wulzen collection)

The glass plates are all housed in archival boxes and are stored vertically as they should be. They are stable in the main vault environment and do not need to be frozen.

B+W negatives and color transparencies (various collections)

The 35mm and 4x5 color transparencies are prone to fading of color dyes and deterioration of the acetate film base over time. These materials are still appear in good condition but they are becoming more acidic every day and will inevitably show the shrinkage and channeling of acetate deterioration unless they are placed in freezing conditions.

The B+W film is a mix of original older film and newer copy negatives. The copy negatives do not need to be frozen, but the older negatives should be. It may be simpler to just freeze everything.

Appendix: Cold Storage of Photographic Materials

Freeze at-risk photographic materials including cellulose nitrate and cellulose acetate based films, and color photographs to extend their useable lifetime and limit the quantity of film degradation products released into the storage area. Research at the Image Permanence Institute shows that cellulose acetate and cellulose nitrate film will deteriorate within an unacceptably short period of time when stored at room temperature. For example, a fresh sheet of acetate film is expected to reach the level of degradation referred to as vinegar syndrome after 40 years at the current temperature and RH of the archives, while the same amount of degradation will take 1500 years when stored at 30F and 30% RH.[1]

Instructions for Cold Storage

Use a frost-free upright freezer (e.g., Kenmore Model #28052, 20.6 cu. ft. Upright Freezer, ~$700.00) in combination with a data logger (for example, Onset HOBO data logger with auto-dialer and remote alarm, ~$300.00) to provide frozen storage for cellulose nitrate and cellulose acetate negatives as well as color photographic materials that are found to warrant long-term preservation. An upright freezer could be installed either within the archives vault or just outside in the archives offices. A 20 cubic foot freezer holds about 15 cubic feet of collections material. Individual packages of photographic materials must be sealed according to the directions on the National Park Service cold storage website.

The primary resource for the implementation of cold storage is the National Park Service's website on Cold Storage of Film-based Photographic Collections:

http://www.nps.gov/museum/coldstorage/

In addition to videos demonstrating the various steps, there are numerous PDFs listed in each section's Resource page which give list of supplies needed, sample freezer maps, how to measure for the correct bag size, etc. The site is very comprehensive.

See below:
Conserve O Gram 14/10: Cold Storage for Photograph Collections – An Overview
Conserve O Gram 14/11: Cold Storage for Photograph Collections – Using Individual Freezer Units
Conserve O Gram 14/12: Cold Storage for Photograph Collections—Vapor-Proof Packaging
IPI's Media Storage Quick Reference

1 Reilly, James M. *IPI Storage Guide for Acetate Film*. Rochester, N.Y.: Image Permanence Institute, 1993.

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Cold Storage for Photograph Collections – An Overview

Introduction

Photographic materials present complex preservation challenges for collection caretakers. Since the introduction of photography in the late 1830's, many different photographic processes and materials have been explored. As photographers experimented with a variety of techniques, they found that photographs changed over time and exhibited certain deterioration characteristics. It is now known that cold storage greatly reduces the rate of deterioration and extends the longevity of photographic media. This preventive conservation measure can help avert or postpone costly conservation treatment of individual objects.

The What and Why of Cold Storage

The term "cold storage" will be used in this *COG* to represent a range of temperatures from 0˚F to 55˚F with an appropriate relative humidity (RH). "Cool rooms" commonly have a temperature of 55-65˚F with an RH of 30-40% while "cold rooms" commonly refers to conditions below 55˚F, and can be as cold as 0˚F.

COOL CONDITIONS	COLD CONDITIONS	
	0 - 55 F	
55 – 65 F	Above Freezing 33 - 54 F	Below Freezing 0 - 32 F

Table 1. Cool and Cold Condition Temperatures.

Because any decrease in storage temperature below ambient conditions improves the longevity of vulnerable materials, the selection of cold storage conditions is based on what is achievable, initially and in consideration of ongoing energy costs and other maintenance issues. Energy costs rise proportionally as storage temperature set points are lowered. For smaller collections, using a few upright household freezer units provides the benefits of low temperature conditions with much less energy use than a large specially-designed cold room. Where collections require the capacity of a cold storage vault, a temperature of 35-50 ˚F is recommended to provide a significant improvement in longevity while keeping costs manageable.

Scientific research by the Image Permanence Institute (IPI), conservation professionals, and others confirms that there is a dramatic increase in film and color dye stability as the temperature and relative humidity in storage are lowered (see table 2). However, while lowering the humidity from 50% to 30% at room temperature can double the life expectancy of film, lowering the temperature has an even more dramatic effect on increasing life expectancy.

Cold storage can help keep the condition of collections "in stasis" until they can be duplicated. Since many collections are near or at the point where significant deterioration occurs, providing cold storage should be the first step in a collection preservation strategy over reformatting or duplication. Focus duplication or scanning efforts on materials that are frequently accessed before placing them in cold storage as it can take many years and significant resources to create copies of large collections.

Temp	RH	Years to Significant Change
75°F	50%	25
75°F	30%	45
55°F	50%	105
55°F	30%	190
32°F	50%	625
32°F	30%	1170
10°F	30-50%	>3700

The IPI Preservation Calculator for Photo Storage at www.imagepermanenceinstitute.org provides an overall 'life expectancy rating' based on known temperature and relative humidity in storage.

Table 2. Average Film Deterioration Rates.

Museum standards for photographic media recommend or require cold temperatures to preserve film and color media. The Code of Federal Regulations - *Facility Standards for Records Storage* (36 CFR 1228.232 (b.) Subpart K, Sept 2005) that applies to federal archives and museums **requires** cold storage for film and color photographic materials at 35F or below and 35%RH. The criteria set by the International Standards Organization (ISO) 18911 - *Safety Film Storage* **recommends** cold storage at 35F or below at 30-40% RH (or cool storage at lower RH) for the extended storage of the above-mentioned materials. Under Directive 1571 - Appendix A the U.S. National Archives and Records Administration lists cold storage as a standard.

Selecting Collections for Cold Storage

All photographic media benefits from storage at temperatures lower than the normal or room temperature conditions generally used for mixed-media museum and archives storage. For more information on the care of these materials refer to *COGs* 14/2, 14/4, 14/6, 14/8, 14/9 and 2/20. However, certain photographic processes, and/or the materials that make up their structure, are particularly vulnerable to rapid deterioration at elevated temperature and RH.

Most historic films and color photographic materials require cold storage for their long-term preservation due to the instability of the plastic supports and/or color dyes. Because most collections contain films and color media that have been stored in unstable environments for decades, rapid deterioration may have already begun. Some older materials may be in advanced stages of deterioration.

Materials that ***greatly benefit from cold storage at temperatures below freezing*** are:

- All cellulose nitrate film-based materials
- All cellulose acetate film-based materials
- All color photographic media; transparencies (slides), prints and negatives

Materials that ***greatly benefit from cold storage*** are:

- Albumen prints
- Deteriorated photographic prints; prints that are very faded or brittle from poor-quality mounts
- Poorly processed prints (which often exhibit staining)

Materials that benefit from cool or cold storage at any temperature but ***are much less vulnerable to deterioration in normal archival conditions*** are:

- Black and white (B&W) sliver gelatin photographic prints

- Polyester-based B&W silver gelatin film-based materials

There are also some materials that benefit from cooler temperature storage, but because of their component structure should not be frozen.

*Materials that **should not be frozen** are:*

- Glass plate negatives and lantern slides
- Cased photographic images; daguerreotypes, ambrotyes, tintypes etc.
- "Instant" prints such as Polaroid® prints (especially integral pack type such as SX-70). Color dyes benefit from cold, but the complex multi-component structure of these prints can be damaged in some situations.

Cold Storage Options

Cool or cold storage for collections can be achieved by installing special climate-controlled storage rooms (cool or cold vaults) or the use of stand-alone freezer or refrigerator units.

Collection size, space availability, and resources will determine which option is most feasible for a particular site. If more than ten standard-size freezers (20-cubic foot capacity each) are required, then a vault may be more practical and cost-effective. Designated parks may have a centralized cold-storage vault available for use as a repository by other sites.

Cold storage requires special handling procedures, and in most cases, specific packaging protocols. The construction of cold-storage rooms requires performance-based procurement specifications to ensure proper fabrication, construction, and subsequent operation. Individual freezer units vary widely in their design and some specific features are desirable when used to store photograph collections. Choosing the right freezer will help maximize the efficiency and performance of your storage. For detailed information on freezer options see *COG* 14/11.

When to Use a Freezer

The most economical method to maintain a cold-storage environment for small collections is to use standard household, upright freezers. Check major national brands as designs change each year. Although these units go through a defrost cycle during which the RH becomes high, this problem is easily and effectively alleviated with proper vapor-proof packaging of the contents. To learn the specifics of packaging for cold storage, see *COG* 14/12.

When considering the purchase and installation of freezers, first determine the specific needs of your collection. This requires a survey of your collection to estimate the packaging needs and the amount of space needed. Consider answers to the following questions:

- How many cubic feet of materials do I have? How much will the collections grow?
- How are items currently stored?
- What are the dimensions of my storage boxes or containers?
- How often is the collection used?
- Are prints or duplicate slides available for research use or will I have to scan some material prior to freezing?
- Will the space to house units be within the museum collection area or are other appropriate spaces available?
- Are resources available to monitor and maintain the environment?

Preparing Materials for Cold Storage

It is critical to maintain physical and intellectual control of collection at all times. Thoroughly organize and document collections before placing them in cold storage. Label all containers/boxes on the outside so that a box can be identified, located and easily retrieved. At a minimum, develop an inventory list and location register to facilitate retrieval and minimize handling.

Separate and remove duplicate photographic prints and slides from materials going into cold storage to maximize the space available for vulnerable media and to keep copies at room temperature for researchers use. (Refer to use of *separation sheets* as outlined in *Museum Handbook*, Part. II Appendix D)

It is not necessary to rehouse collections prior to cold storage unless the enclosures and or boxes are extremely brittle or structurally unsound. Cold storage slows down all deterioration processes for collections materials and for the enclosures.

Use appropriate vapor-proof packaging for the collection containers if the cold storage room or unit does not have RH control. See *COG* 14/12.

Duplication or Digitization Before Cold Storage

Although traditional photographic duplication for archival masters and digitization for "use copies" is encouraged, reformatting is not always feasible or necessary before collections are placed in cold storage. Where prints or duplicate slides exist, these can be used as reference copies from which scans may often be made (instead of using the negatives or master slides). If feasible, heavily used items or small collections for which prints or duplicates are not available can be scanned to create "use copies" prior to being placed in cold storage. This makes them less subject to excessive handling. Materials can always be pulled from cold storage as digitization projects are implemented.

Access to Materials in Cold Storage

Acclimatizing or warming up cold materials to room temperature before they can be used delays access to collections in cold storage. If the contents are sealed in vapor-proof packages, the packages can be placed on a table or shelf at ambient conditions to warm up to room temperature. Place items or containers that are stored in RH-controlled cold storage rooms without special sealed packaging in a plastic bag before removing them from the cold room. The bagged items may safely warm up in the staging area. Acclimation can also be done using an insulated storage container (picnic cooler) where ambient conditions are excessively warm or humid or when materials need to be transported outside of a building.

To maintain the preservation benefit of cold storage, items should not be removed more than a few times per year or for long periods of time. Leaving the materials at room temperature diminishes the benefit of time spent in cold storage.

Maintenance and Equipment Failure

An important part of any cold-storage program requires proper maintenance of equipment according to manufacturer-supplied user manuals and the implementation of monitoring programs to ensure years of trouble-free operation.

The least problematic failure of a cold unit is a power outage or total breakdown of the equipment causing shut off and gradual warming to ambient conditions. As long as the cold unit is kept closed and any vapor-sealed packages remain intact, there is generally low risk to the contents. However, in rare mechanical failures, the unit may heat up inside. Failure of RH controls in vaults where protective vapor-proof packaging is not normally used can result in RH spikes up to 100%, causing the vault walls and ceilings to weep, and paper boxes to swell with moisture. In these situations, the unit must be shut down, doors opened to reduce heat or humidity, and contents removed if they are not packaged. Damp materials must be dried out immediately.

Although freezers and cold storage rooms may have audible alarms, it is best to have remote monitoring that signals a 24/7 remote monitoring station or dials a 24-hour emergency phone, especially where no staff is present during off hours. See *COG* 14/11.

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The series is distributed to all NPS units and is available to non-NPS institutions and interested individuals on line at < http://www.nps.gov/history/museum>. For further information and guidance concerning any of the topics or procedures addressed in the series, contact NPS Park Museum Management Program, 1849 C Street NW (2265), Washington, DC 20240; (202) 354-2000.

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Cold Storage for Photograph Collections – Using Individual Freezer Units

Introduction

Most photograph collections can benefit from cold storage. When collections are relatively small, and space and budget is limited, the use of one or more household "upright" freezers is a viable option. To ensure the collections are properly protected, consider freezer specifications, location, collection size, collection packaging requirements, and inventories when planning to use an upright freezer.

Types of Freezers

This *COG* focuses on the use of household upright freezers because of their ease of availability, low price, and efficiency. The capacity of the largest househould freezer is about 20 cubic feet. There are however, several other available freezer options.

Household "chest" freezers are similar in function to the "upright" models. They can work as a cold storage unit, but they are not the best choice for long-term collection storage. Boxes need to be stacked in a chest freezer to best use the interior space. The weight of some boxes may be detrimental to the safety of the lower boxes. Collections are not easily accessed since finding one item in a chest freezer often means removing or displacing several other packages. The less handling of collections the better because film can become more brittle at very cold temperatures.

Specialty freezers such as commercial, industrial, and scientific freezers offer a few more desirable features than household models, depending on the collection. They often allow for more adjustability of shelving placement, which is essential to efficiently pack a collection. Some of these freezers are available in large capacity models, up to 70 cubic feet of capacity.

While these large-capacity freezers can be useful for medium-sized collections, they tend to be more expensive than several upright household units combined. They also usually run louder and produce more heat than most household models. If a large-capacity specialty freezer fails, it places the entire contents at risk. Several smaller household units generally operate reliably. If one fails the rest of the collection is still maintained by the other freezers. Beyond more than a few household freezers, the electrical circuit load could become an issue.

Flammable Material Storage (FMS) Freezers
This specialized freezer accommodates the needs of materials such as cellulose nitrate film. It was designed to contain and isolate vulnerable collections. If your collection contains a large amount of cellulose nitrate film see *COG 14/8* for more information on appropriate storage.

Household "Upright" Freezer Specifications

There are many options in terms of household "upright" freezer design and operation.

Note: This *COG* does not make specific recommendations as to brand name products as model numbers and features change very rapidly and would soon be outdated. Therefore, always consider the following features when selecting the appropriate freezer to suit your collection needs and maximize available resources:

- **Frost-free or self-defrosting**. The freezer should be "frost-free" or self-defrosting. This eliminates the inconvenience of periodically shutting down and defrosting the unit which necessitates the removal of the collections during that process. During the defrost process the relative humidity (RH) in the freezer increases significantly. However, this is temporary; collections will be protected from experiencing dramatic changes in RH because of proper vapor-proof packaging (see *COG* 14/12).
- **Energy efficiency.** Current government regulations for federal agencies require that all appliances purchased must qualify as Energy Star ® or consume "low energy" whenever possible. This requirement also helps to keep energy costs down, especially when operating several units.
- **Minimal heat generation.** Storage space for collections is often at a premium with freezer units frequently placed within existing collection storage areas. It is therefore important that freezers do not generate a lot of heat during operation. Excess heat given off by the freezer can adversely effect other collections by counteracting climate control systems. Most freezer specifications do not mention heat generation. Always check with the manufacturer's sales representative, and if possible visit a local store to see the model in operation before selecting one.
- **Minimal ambient noise.** Seeing the freezer in working mode prior to purchase helps determine the amount of ambient noise given off by the freezer. Freezers may be housed close to office spaces, where noise could be a problem. Some newer models run very quietly.
- **Adjustable shelving.** Adjustable shelves allow for the best use of space based on container sizes. However, many household upright freezers have fixed shelves that limit the available useful space. Look for a model that has the most options for adjustability. Door bins can be used to house narrow boxes and motion picture cans.
- **Removable door bins or door panels.** Some freezers allow individual door bins (see figure 1) or the entire door panel to be removed. If the entire panel is removed it can be replaced with a flat sheet of polystyrene. Either of these options increases the usable space by allowing extra deep or large double-shelved boxes to overhang the shelf and protrude into the door space.

Figure 1. This door bin/shelf can be removed to accommodate the box overhang, allowing for maximum use of space.

- **Heavy-duty wire shelving.** Heavy-duty wire shelving is often preferable to glass shelves because of its rigidity and weight-bearing strength. Heavy collection material may crack a glass shelf. However, the wire shelving can leave an impression on the bottom of your storage box. Line shelves with material such as Ethafoam™ or Coroplast™ or with 3/8" – ½" acrylic sheeting (Plexi-glas®) for rigidity (see figure 2).

Figure 2. Ethafoam™ sheets used to line wire shelves.

- **Locking mechanism.** Some freezer models offer locks to help ensure that the door has been closed properly after use. They also help to deter staff from opening the freezer frequently or storing non-collection materials inside.
- **Audible alarms.** Some freezers come with alarms that sound when the inside temperature is too high, indicate that the door is open or there is a system malfunction. An LED temperature read out (digital display) on the outside provides visible confirmation that the unit is operating correctly.
- **Remote monitoring capability.** Freezers with remote monitoring capability dial a 24-hour emergency phone or signal a 24/7 remote monitoring station to alert off-site staff. These include auto-dialer datalogger alarms that insert a sensor into the unit to dial a telephone number if the freezer warms above a certain temperature. Some units can be hard wired into a building monitoring system. Wireless alarm systems can also be used with building-wide monitoring systems.
- **Service contracts.** Make sure you understand the equipment and maintain service contracts or warranties. If your freezer malfunctions you want to have reliable service providers that can respond quickly and make the needed repairs.

Determining Your Collection Need

When considering the use of household "upright" freezers, obtain a reliable estimate of the overall size of your collection, the dimensions of storage boxes, and potential for growth. This means collection data will need to be gathered through a general survey of collections.

Be aware that the actual capacity of a freezer may be less than is what is stated in the specifications for that model. For example, on average a 20-cubic-foot household upright freezer provides only about 15 cubic feet of space for collection materials. This is due to limitations caused by shelving configurations, various box sizes, the placement of interior air vents that cannot be blocked, (see figure 3), and limited usability of shallow door bins.

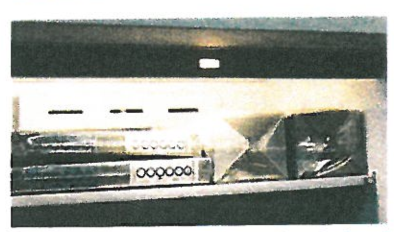

Figure 3. Do not cover air vents, such as the slotted ones in the back of this freezer, with boxes.

Housing the Collections

All collections must be boxed, placed in binders, or otherwise housed in an outer container for freezer storage to ensure collections can be safely placed in the freezer.

Measure the outer dimensions of storage boxes, including protruding lids and/or clasps and assume the outer vapor-proof packaging will add ¼" to each dimension. Compare these dimensions with the interior dimensions and configuration of the storage unit. In some cases, rehousing portions of collections may be necessary to best use available space.

Plan how the boxes and binders can be most efficiently configured and shelved within the freezer. For example: consider a standard archival box, approximately the size of a shoebox or 12 x 5 x 6 inches that are often used to house 4 x 5 inch negatives. Shelf dimensions for a 20 cubic foot household freezer are approximately 26 inches wide by 17 to 21 inches deep. Four of these boxes can be stacked two high and two across in about one cubic foot. Due to shelving configuration, approximately 30 to 40 standard shoeboxes can be shelved in a 20 cubic foot household upright freezer. (see figure 4)

Figure 4. A freezer filled with properly packed boxes. Labels face forward for easy retrieval.

Most small collections can be adequately accommodated by using one or two household "upright" freezer units. If the number of freezer unit exceeds ten (10), then consider using a storage vault.

Vapor-proof Packaging for Freezer Storage

Proper use of freezers for storage requires vapor-proof packaging of each box. Items to be stored in freezers require protection from fluctuating and/or high relative humidity within the unit, and from condensation on the boxes when the doors are opened and/or when the boxes are removed to room temperature. The packaging, discussed in *COG 14/12*, involves the use of a double bagging system to create a vapor-proof enclosure for each collection container.

Collection Preparation and Access

Collections stored in freezers cannot be accessed at the box or item level until the vapor-proof package is removed from the unit and allowed to come to room temperature. Once at room temperature, the protective vapor-proof packaging may be removed and the individual item accessed.

Therefore, before collections go into cold storage complete all basic processing, including inventorying, identifying box contents, and creating box lists. This will allow the appropriate boxes to be pulled from the freezer, brought to room temperature, and the particular item retrieved. Post a shelf map of the boxes on the freezer to aid retrieval, reducing the need to leave the freezer door open for long periods and pulling out many boxes unnecessarily.

Maintenance and Equipment Failure

Freezers can provide many years of trouble-free service. However, they do require minimal maintenance such as semi-annual vacuuming of condenser coils, and the rare replacement of door gaskets that no longer seal well. The latter causes frost to build up and the unit to consume excess energy.

The least damaging equipment failure for collections is a power outage or total breakdown of the cold unit when the unit shuts off and gradually warms to ambient conditions. *As long as the freezer is kept closed and unplugged, and the vapor-sealed packages remain intact, there is generally low risk to the contents.* However, rare mechanical failures may cause the unit to heat up inside. In these situations, the power must be shut down and the doors opened to reduce heat or humidity. If contents feel warm or the vapor-barrier has failed remove the containers and allow them to cool and dry out.

Although some freezers may have audible alarms, they may not be heard when staff is not present or during off-hours. Therefore, it is best to have remote monitoring capability that dials a 24-hour emergency phone or signals a 24/7 remote monitoring station, as described above. Where there is 24-hour guard surveillance with periodic rounds, it may suffice to have a remote intercom system that allows the sound of the alarm buzzer to be heard in outer offices or at a guard station.

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Conserve O Gram

April 2009 Number 14/12

Cold Storage for Photograph Collections – Vapor-Proof Packaging

Introduction

This *Conserve O Gram* outlines a packaging system for items in cold storage that helps to maintain the desired microclimate inside individual containers. It also prevents condensation from forming on the objects due to high relative humidity (RH), dramatic changes in RH, or moving directly from the cold to room temperature. Proper packaging techniques, especially the use of vapor-proof packaging, is essential for all cold-storage freezer units and simple cold rooms that do not have interior relative humidity (RH) control.

The Packaging Concept

Cold storage units without RH control, which include all household freezers, experience numerous daily changes in RH as they go through the defrost cycle. This rapid fluctuation of RH can put undue stress on collections. Proper packaging alleviates this problem because the interior of the package does not respond to the change in RH experienced by the freezers.

Testing shows that the RH in the freezers may go from 65% to 85% over the course of an hour, but the RH inside the packages will only change about 1% within the same time frame. This small RH change also occurs in film-based materials as they are taken out of cold storage for access. Condensation forms on the outside of the packages, but the barrier created by the packaging does not allow the materials inside to take on additional moisture.

Constructing the Package

Double-bag the outside of boxes or containers using appropriate methods and materials to ensure the preservation and safety of collections while in cold storage.

Use good-quality vapor barrier film for an inner bag. This film has a multi-layer structure incorporating polypropylene or polyethylene with a very thin metal sheet or fine metallic dispersion.

Some examples of acceptable barrier films for vapor-proofing in cold temperatures are Marvelseal®, Dri-Shield™, and Static Shield™. However, Marvelseal® and Dri-Shield™ are opaque due to a metallic layer, making it difficult to monitor the interior of the bag. Static Shield™ bags, widely used for packing computer components, are "semi-transparent," making it possible to read box labels through the bag (see figure 1).

Figure 1. Semi-transparency of Static Shield™ bags allows for readable text.

Use heavyweight (6 mil is preferred) polyethylene, "press-to-close" (zipper-lock) bag for the outer bag. This durable outer layer gives extra protection from condensation as the bags are removed from the freezer and helps prevent damage or tears to the inner bag as items are moved and stacked.

Reduce the amount of air trapped inside the boxes and bags before closing and seal with clear plastic packaging tape. If excess air is trapped inside the bags the packages will tend to puff up or "pillow". This affects the microclimate, makes the packages difficult to stack and retrieve from the freezer, and puts pressure on bag seams and sealed closures.

Preparation of Materials

Maintain physical and intellectual control of objects that are placed in cold storage. Prior to placement into cold storage, prepare a box-level inventory indicating the range of item numbers or contents of each box, and the box number in that series.

Separate photographic prints from their corresponding negatives prior to introduction into cold storage. This provides more space in the freezer for additional high-risk collections and allows the print to be stored at room temperature for use by researchers. Use separation sheets as outlined in the *Museum Handbook*, Part II Appendix D http://www.nps.gov/history/museum/publications/handbook.html. Enter the new storage location into the Automated National Catalog System databases.

Use white, paper, foil-backed labels to identify the contents of all boxes/containers and adhere them in two locations (on two sides of the box). Applying two labels to each box helps to ensure one will be visible however the boxes are arranged in the freezer. Printed labels or hand-written ones in graphite are appropriate. Include the catalog or archival series number, and specific storage location to facilitate retrieval.

Determining Bag Dimensions

Ensure that the storage bags properly fit the box or container. Measure each container or box to determine the appropriate bag dimensions. Make sure to measure the largest dimensions including protruding lids and/or clasps. The following will assist in calculating the correct bag size for the inner and outer bags:

- **Width**: Measure the container/box width (or shortest side). Add container/box height to this measurement, plus an additional inch. This figure is the estimated width of the bag to be used for packaging.
- **Length**: Measure container/box length (or longest side). Add container/box height to this measurement, plus an additional inch. This figure is the estimated length of bag to be used for packaging.
- **Ordering bags**: Order bags closest in dimension to the estimated measurement

you calculated. Round up to the closest size bag available. It is desirable for the open end of the bag to be on the shorter dimension. This will help minimize the size of the opening that needs to be sealed. If possible, make a "mock-up" before ordering large quantities.

Relative Humidity Indicator Cards

Because monitoring the RH plays an important role in maintaining a good cold storage environment, each vapor-proof package includes two RH indicator cards. There is one for each bag layer, as outlined in the packaging procedures below. Color changes in the cards will indicate if either the inner or outer bag is leaking due to holes.

This type of indicator card relies on the reaction of cobalt salt to the moisture content of the air. It is temperature sensitive and reads higher than the actual RH when placed in very cold conditions. Cards will tend to read 5% higher at 35°F and 10-15% higher when the temperature is below 20° F.

To monitor your bags for leaks, record the RH of the containers once they have come down to the temperature in the freezer. This is your baseline RH of the newly frozen packages. If, over time, the RH rises substantially above the baseline RH, the bags may have a leak. In that case, remove the container. If, after coming to room temperature, the RH is still very high, the bag has a leak and needs to be replaced. Check packages every three months for a change. As long as the frozen temperature RH reads 50% or less (especially in the inner bag) there is little cause for concern. Packages reading 90-100% RH require immediate attention.

Packaging Procedures

First, assemble all supplies and tools including:

- Barrier bags (inner bag)
- Polyethylene bags (outer bags)
- Cobalt salt humidity indicator cards
- Archival double-sided tape
- Packaging tape
- "Filler" material: Ethafoam™, crumpled archival paper, mat board or corrugated plastic etc.
- Scissors, pencils, paper, foil-backed labels, bone folders, linen twill tape, weights

Select a space for packaging with an RH that does not exceed 50%. If you cannot find a space with an RH less than 50%, lower the room RH with a room dehumidifier. Scheduling large packaging projects for winter (or dry season) makes this easy.

If your collection is not stored at or below 50%, let your collection equilibrate to these drier conditions prior to packaging if possible.

Once boxes or containers are inventoried, and labeled, fill any empty air space in boxes with "filler" material to prevent shifting (see figures 2 & 3).

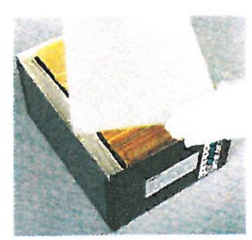

Figure 2. Filler material is placed along one side and on the top to completely fill all extra space.

Figure 3. Roll small pieces of Ethafoam™ and tie with twill tape and use to fill voids in boxes.

Place a cobalt salt humidity indicator card on the box next to the label, in a location that will be visible after packaging. Use two strips of archival double-sided tape on the reverse to adhere the card to the box. Avoid placing the tape directly behind the indicator spots.

Insert the box or container into the first barrier bag with the front (labeled end) of the box towards the back of the bag. If using Static Shield™ bags, the label should be readable through the bag and not obscured by seams or fold overs.

Squeeze out the excess air in the bag by pressing with hands along the box sides and top. Small weights or strips of Plexi-glas® placed on top of the box can assist with this process and help to secure the bag for wrapping. "Gift wrap" the box by neatly folding up any excess bag materials at sides by forming creased flaps. Secure the flaps to the sides with packaging tape (see figure 4). After applying the tape use a bone folder to ensure it is adequately adhered (see figure 5).

Align the edges of the open end of the bag and fold the excess at least once in 1-inch increments. Lay the folded section along the end of the box, and tape it down across the length, sealing it against the box. Leave a tab at the end of the tape by folding over its end to aid in later removal during pulling and reuse when re-filling the box.

Figure 4. Inner bag being wrapped. Excess material and flaps are tightly secured with tape along the sides.

Figure 5. A bone folder is being used to "burnish" tape to ensure it adheres to the package.

Place a second RH indicator card on the outside of the vapor-proof inner bag near the first humidity card so they can be monitored together easily by observing only one side of the box.

Insert the front end of the vapor-sealed box into the heavy-weight polyethylene bag so that the RH indicator cards are clearly visible once the outer bag is sealed.

Repeat the above wrapping procedure for the polyethylene bag. Close the zipper closure and tape it flat against the box taping over the entire end to keep it intact and provide an additional seal (see figures 6 & 7).

Figure 6. The sealed "zipper-lock" end of the outer bag is taped flat to the box.

Once all the boxes are sealed in their bags they can be placed in the freezer unit. Where possible, store in numerical order for ease of access. However, if this is not possible due to the interior dimensions of the freezer and types of boxes, fit the boxes to maximize storage and use the door bins for smaller materials.

Figure 7. This box is completely wrapped and ready for the freezer.

Prepare a shelf map that indicates where each box is located inside the refrigerator to facilitate retrieval. Place the shelf map and the inventory list on the refrigerator door with a copy of the guidelines for freezer storage and emergency contact information.

Accessing Collections in Cold Storage

To access collections for use (or to replace leaky bags), remove box from unit and let it warm to room temperature (65-75F and 30-50% RH) to prevent damage. **DO NOT** remove the vapor-proof bagging until all contents are warmed up. The containers can be placed on a work table or shelf during the acclimation time. Because water will condense on the outer package, place a blotter or towel underneath the container to wick up excess water. Acclimation can also be done using an insulated storage container (picnic cooler) where ambient room conditions are excessively warm or where materials need to be transported outside of a building. Place the sealed package in the cooler until it arrives safe at its destination and allow the package to thoroughly warm up.

Warm-up time varies with box size. Generally, you should wait eight hours or overnight, before opening the bag. Be sure to mark the box with a "caution" or "object" sign to highlight collections materials to other staff together with the estimated time it will be safe to open the bags.

Once the bag has acclimated and is no longer cool to the touch, wipe off any moisture with paper towel and open the bag by removing the tape. Discard the tape and replace any leaking bags.

When only a few items are needed for extended periods, repack the rest of the box and return to cold storage. Once the materials are ready to be returned to cold storage, special humidity conditioning with a dehumidifier is not usually required prior to re-packing unless environmental conditions exceed normal office/collection storage parameters (e.g., 72°F/50%RH).

To maintain the preservation benefit of cold storage, negatives, transparencies, and slides should not be removed more than a few times per year or for long periods of time.

Sources

Barrier Bag (inner bag) Static Shield Bag Type 111™ - open end
Uline www.uline.com
Tel 800-295-5510
Note: There are several other types of barrier bags and sheet films available.

Polyethylene Bag (outer bag) plain, clear, "press to close" (zipper-lock), 6 mil (thickness)
McMaster-Carr www.mcmaster.com
Tel 330-995-5500

Other supplies including *packaging tape (3M™ #313), archival double -sided tape (3M™ #415), cobalt salt humidity indicator cards, bone folders, weights, foil- backed labels and filler materials (Ethafoam™ sheets, twill tape, archival paper etc.)* can be purchased from suppliers of conservation and archival-quality materials.

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IPI Media Storage quick reference

2nd edition

by **Peter Z. Adelstein**, *Image Permanence Institute*

Negatives
Prints
Tapes
CDs
DVDs

STORAGE is the single most important factor determining the useful life of modern information media. (For electronic media, copying and format obsolescence are also important, but those issues are beyond the scope of this publication.) The *IPI Media Storage Quick Reference* (MSQR) attempts to explain the role of storage conditions—that is, temperature (T), relative humidity (RH), and air quality—in the physical survival of photographs, films, audio and video tapes, CDs, and DVDs.

Research shows that lower temperature and RH can greatly improve material stability, a fact reflected in the standards published by the International Organization for Standardization (ISO). The ISO standards recommend climate conditions for the storage of specific media, and when possible, these recommendations should be followed. The standards are less helpful, however, when it comes to assessing how a particular environment will affect a collection or deciding on the best environment for storing a collection that contains media of different types—common concerns among collection managers. The purpose of the MSQR is to distill and present, in one publication, the information you need to make informed decisions about the storage of the mixed collections of photographic, magnetic, and optical media in your care.

CONTENTS

Media Index

USING THE MSQR

Decision-making about new or existing storage facilities usually starts with one of three key questions:

- **How good (or bad) are my existing storage conditions?**
- **What storage conditions should I have for the media in my collection?**
- **What storage compromises can I safely make for my collection of different media types?**

These questions are answered throughout this booklet and on the MSQR wheel.

The Booklet

These pages are not laid out in strictly linear fashion for cover-to-cover reading but rather in discreet blocks of interrelated information as illustrated in Fig. 1. You may find it useful to browse for the topics that interest you most. Table 3 on p. 5 is literally and figuratively the centerpiece of the MSQR. It presents an overview of the suitability of storage environments for various media types. Preservation issues related to specific media can be found in tan boxes throughout the booklet; each box contains information about a specific medium, including structure, particular preservation concerns, ISO recommendations, and simplified storage recommendations. The light blue boxes present important side issues such as low-temperature storage, enclosures, environmental assessment, and condition assessment.

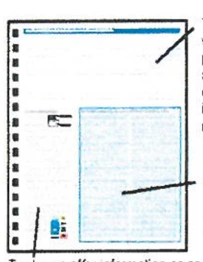


Fig. 1. Guide to navigating the MSQR.

The Wheel

An important component of the MSQR is the two-sided wheel (Fig. 2), which can be found in the pocket at the back of the booklet. Side 1 of the wheel, the Media Storage Summary, provides a medium-by-medium overview of preservation issues (kinds of decay or other problems), recommendations (key storage considerations), and simple guidance on the suitability of four typical environments, ROOM, COOL, COLD, and FROZEN. The Media Support Chronology on Side 2 is a guide to the types and dates of use of nitrate, acetate, and polyester plastic supports for various film and magnetic tape media.

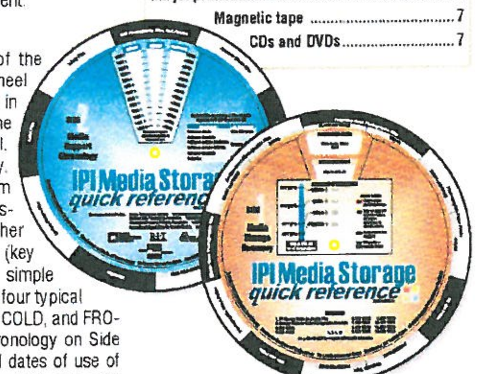


Fig. 2. The Media Storage Summary is on Side 1 of the MSQR wheel. The Media Support Chronology is on Side 2.

A FRAMEWORK for MEDIA PRESERVATION

Without a lock on the door, a roof overhead, and some degree of orderly arrangement, a media collection has little chance of survival. Once these basic conditions for preservation are satisfied, however, the most urgent problem is slow but steady decay. Some media, CD-ROMs, for example, decay slowly and can tolerate a variety of storage conditions. Most other media decay much faster and need special environments to have a long useful life.

Each medium has its Achilles' heel and its own special requirements. The dyes in color photographs spontaneously fade at room temperature in a rather short period of time; low-temperature storage is the only way to preserve them. Black-and-white photographic prints don't require low-temperature storage, but the silver particles making up the images are very sensitive to high humidity and airborne contaminants. Media preservation depends on our understanding of the vulnerabilities of each media type so that we can provide the proper storage conditions. For new, undeteriorated materials that will be kept in purpose-built storage facilities, this task is relatively straightforward. But when some elements of the collection are older or already deteriorated, storage conditions that dramatically slow down the rate of deterioration are in order. In practice, you must know the current decay status of your collections and have reliable data on their actual storage conditions. You need three pieces of information to make good storage decisions:

- **The behavior of the different media types in your collection**
- **Their current state of preservation**
- **The prevailing storage conditions.**

The Three Categories of Environmentally Induced Decay

The three general categories of environmentally induced deterioration are biological, chemical, and mechanical (or physical).

Biological Decay

Biological decay includes all the living organisms that can harm media. Mold, insects, rodents, bacteria, and algae all have a strong dependence on temperature and RH. Mold and mildew are serious dangers to media collections. Sustained high RH (above 70% or so for more than a few days) should be avoided.

Chemical Decay

Chemical decay is due to spontaneous chemical change. Fading of color dyes in photographs and degradation of binder layers in magnetic tape are examples of decay caused by chemical reactions occurring within the materials themselves. The speed of these reactions depends primarily on temperature, but moisture also plays a role. In general, the warmer the temperature of the storage area, and the higher the RH, the faster the media collection will be affected by chemical decay. Chemical decay is a major threat to media that have color dyes and/or nitrate or acetate plastic supports. COLD storage is recommended for these materials; FROZEN is recommended when signs of deterioration are present.

Mechanical Decay

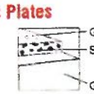
Mechanical forms of decay are related to the changes in size and shape of water-absorbing materials such as cellulosic plastic film supports or the gelatin binder in photographic materials. RH is the environmental variable that determines how much water is absorbed into collection objects. When the RH is very low (below about 15%) for long periods of time, objects lose moisture and shrink. The opposite is true when RH remains high (above 70%). Expansion due to extreme dampness and contraction due to extreme dryness cause stresses among the layers of media objects, which can lead to permanent deformation and layer separation.

Excessive dampness is a very serious environmental threat to media collections, because it contributes not only to mechanical decay but to biological and chemical decay as well.

Photographic Glass Plates

STRUCTURE

Silver image particles in a gelatin binder on glass support.



PRESERVATION ISSUES

Decay Related to Temperature and RH

- **Silver image decay**
- **Glass deterioration**
- **Layer separation.** The glass support is dimensionally stable in changing humidity, but the gelatin binder is not and will contract at low humidity. If the stress between the contracting binder and the glass is greater than the adhesion between the gelatin and the glass, the two layers will separate.
- **Mold**

Other Concerns

- **Harmful enclosures**
- **Breakage. Handling and enclosure guidelines are given in ISO 18918.[7,12]**
- **Poor air quality**

ISO RECOMMENDATIONS[7]

Max temp: 64°F (18°C). RH from 30% to 40%. Lower humidities can cause layer separation.

SIMPLIFIED STORAGE RECOMMENDATIONS[12]

COOL temperature ensures greater protection from image decay. COLD and FROZEN offer marginal benefits.

ROOM	Fair
COOL	Good
COLD	Very good
FROZEN	Very good

Decay Caused by Improper Storage

The ten types of decay listed in the table are major threats to media collections. Some forms of decay may affect only one media type; others may affect several types. The good news is that the proper environment will effectively minimize the risk of decay-related damage.

Table 1: The types of decay that threaten media, the media that are affected, and recommended storage environments.

TYPE of DECAY	MEDIA	RECOMMENDED ENVIRONMENT
SILVER IMAGE DECAY	Photographic glass plates Black-and-white film Black-and-white photographic prints	30% to 50% RH
COLOR IMAGE DECAY	Color film Color photographic prints Ink jet prints	Low temperature 30% to 50% RH
COLOR BLEEDING	Ink jet prints	30% to 50% RH
YELLOWING, STAINING	Color photographic prints Inkjet prints	Low temperature 30% to 50% RH
BINDER DEGRADATION	Magnetic tapes	Low temperature 30% to 50% RH
NITRATE DECAY	Nitrate-base film	Low temperature 30% to 50% RH
ACETATE DECAY	Acetate-base black-and-white film Acetate-base color film Acetate-base magnetic tape	Low temperature 30% to 50% RH
GLASS DETERIORATION	Photographic glass plates	30% to 50% RH
LAYER SEPARATION	Photographic glass plates CDs and DVDs	Minimal temperature and RH fluctuations 30% to 50% RH
MOLD	All media	30% to 50% RH

Assessing Your Environment

Getting Data

Knowing the temperature and RH conditions in your storage environment is a critical part of preservation practice, but this is impossible without reliable data. Storage areas should be continuously monitored. Electronic temperature and RH sensors that allow data to be analyzed on computers are preferable; sophisticated analysis or visualization of long-term trends is difficult to do with chart recorders. Many kinds of electronic dataloggers are available on the market. In some cases, temperature and RH data may be obtained from computerized systems that control the air-conditioning equipment in buildings.

Fluctuations

Fluctuations in temperature and RH are always a concern in environmental assessment. Fortunately, short-term RH fluctuations generally are not much of a threat to media collections and should not cause alarm. The level of sensitivity to environmentally induced mechanical damage is fairly low for most media. In addition, enclosures such as boxes and cans tend to buffer fast RH changes. Maintaining steady conditions should not be the objective, if it must be achieved at the cost of low temperature and RH. For the stability of media collections, the key concerns are long-term average temperature and RH and the profile of seasonal changes. The most important environmental trends are usually seasonal in nature.

IPI Analysis Tools

IPI has developed a web-based data analysis platform especially for the complex job of analyzing temperature and RH data. The web application offers the possibility of storing a large number of data sets, and it performs quantitative determinations of the overall rate of chemical decay and the risk of mold growth, mechanical damage, and corrosion tailored to the specific needs of library, museum, and archival collections. IPI has also developed the PEM2*, a data logger designed explicitly for preservation use. With these tools it is possible to perform environmental risk assessments that relate directly to preservation concerns. More information can be found on the IPI web site: www.imagepermanenceinstitute.org.

Condition Assessment—A-D Strip Testing for Acetate Film Collections

Acetate-base materials are inherently prone to a type of chemical decay known as vinegar syndrome.1 As the decay progresses, materials become more acidic, degrade at an ever faster rate, and eventually are irreversibly damaged. Unless preventive measures are taken, any acetate-base collection eventually will be lost. To know the risk of material loss in your acetate collection and implement a sound preservation strategy, you must first know the overall condition of the collection.

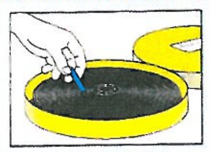


Fig. 4. Testing with A-D Strips.

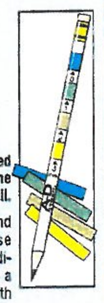


Fig. 5. Strip color is compared to the color scale printed on the accompanying pencil.

What Are A-D Strips?

A-D Strips are used to determine the extent of chemical decay in acetate-base collections. These small indicator papers turn from blue, through shades of green, to yellow in the presence of the increasing amounts of acidic vapor given off by decaying acetate. In this way, the strips indirectly measure the degree of decay in an acetate material. Fig. 3 illustrates the relationship between the color change in an A-D Strip and rising acidity in a decaying acetate material. Four color levels (ranging from A-D Strip level 0 to A-D Strip level 3) characterize the advance of decay. The higher the number, the greater the risk of material loss due to acetate decay. At A-D Strip level 2 physical property changes (e.g., brittleness, distortion, or shrinkage) are imminent.

The testing method is simple. An A-D Strip is placed in a confined space with the item to be tested (Fig. 4). After exposure, the resulting strip color is compared to the A-D Strip color scale (Fig. 5). Information about A-D Strips and their use can be found in the User's Guide for A-D Strips (available on line at www.imagepermanenceinstitute.org).

Testing—Which Materials, How Many Samples?

Acetate-base materials include film (both still and moving images) and magnetic sound recordings. Collections of these materials are often large, and condition evaluation is essential. Testing a random sample of a collection with A-D Strips can give an idea of the collection's overall condition. The sample size will depend on the size of the collection and the desired level of confidence in the data analysis. Statistical models can be applied. As a rule of thumb, randomly testing about 1,000 items will provide sufficient information for a collection of 10,000 items or more. The task of testing every item in a large collection is daunting and is usually impractical; it is best to start by testing a random sample. If pockets of materials are found to be affected by acetate decay, these could be tested further, if desired, after the overall condition is assessed or whenever institution resources make it possible.

What Do We Do with the Results?

Be prepared to act on your survey results. Now that you have a general picture of the collection's condition and know whether or not the situation is urgent, you can respond appropriately. Most importantly, the data will tell you how much of the collection is in critical condition. Acetate materials displaying A-D Strip level 2 or above are considered to be in poor to critical condition and should be stored under FROZEN conditions (see Table 3) and/or duplicated. COLD storage conditions are fine for collections unaffected or only slightly affected by acetate decay. Condition assessment tells us what type of storage the collection requires. A well-balanced strategy will involve providing adequate storage, prioritizing duplication, and planning ongoing condition monitoring.

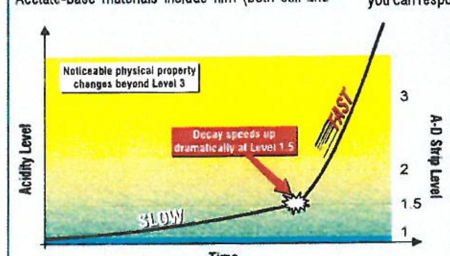


Fig. 3. Relationship between A-D Strip levels, film acidity, and film condition.

Should Degraded Nitrate and Acetate Film Be Segregated?

Nitrate and acetate films that have already deteriorated can emit acidic gases that may be absorbed by other film stored nearby. It is possible that absorption of acidic and oxidizing vapors from degrading films can accelerate decay among undeteriorated films in the same storage area. Severely deteriorated *nitrate* films (those showing extreme brittleness, gelatin softening, and other signs of advanced decay) should be removed from collections and safely disposed of. In practice, however, it *usually is not practical or desireable* to separate either degraded acetate or early-stage deteriorated nitrate film from the rest of the collection. The rate of decay of "good" film depends much more heavily on temperature than it does on the amount of acid vapor the film may have absorbed from "bad" neighbors. In addition, adequate ventilation and fresh air exchange can greatly mitigate the threat of contamination.

Nitrate-Base Photographic Film

STRUCTURE
Silver image particles in a gelatin binder on nitrate base.

PRESERVATION ISSUES

Decay Related to Temperature and RH

- **Silver image decay**
- **Nitrate decay.** May cause yellowing, buckling, distortion, and shrinkage of film and corrosion of metal cans. Can also cause silver image decay.
- **Binder degradation.** Nitrate base decay may cause gelatin binder to become soft or sticky.
- **Mold**

Other Concerns

- **High flammability**
- **Harmful enclosures**
- **Poor air quality**
- **Off-gassing.** Degrading nitrate base emits acidic and oxidizing gases that threaten nearby materials.

ISO RECOMMENDATIONS[3]
Max. temp: 36°F (2°C). RH from 20% to 30%.

SIMPLIFIED STORAGE RECOMMENDATIONS[12]
COLD is consistent with the ISO recommendation. If there is evidence of base degradation, FROZEN should be used.

ROOM	No
COOL	No
COLD	Good
FROZEN	Very good

Acetate-Base Photographic Film

BLACK-AND-WHITE

STRUCTURE

Silver image particles in a gelatin binder on acetate base. Some sheet films may have a gelatin backcoating.

PRESERVATION ISSUES

Decay Related to Temperature and RH

- **Silver image decay**
- **Acetate decay.** May cause distortion, shrinkage, and brittleness. Often detected by vinegar odor (vinegar syndrome); severity can be determined with A-D Strips.
- **Mold**

Other Concerns

- **Harmful enclosures**
- **Poor air quality**
- **Outgassing.** Degrading acetate releases acidic gases that threaten nearby materials.

ISO RECOMMENDATIONS[6]

Max. temp. depends on max. RH.

36°F (2°C) max. temp. for 50% max. RH.

41°F (5°C) max. temp. for 40% max. RH.

45°F (7°C) max. temp. for 30% max. RH.

SIMPLIFIED STORAGE RECOMMENDATIONS[12]

COLD with 50% max. RH is similar to the ISO recommendation. If the A-D Strip reading is 2 or greater, film should be stored at the FROZEN condition and duplicated as soon as possible.

ROOM	No
COOL	No
COLD	Good
FROZEN	Very good

COLOR

STRUCTURE

Organic dye image layers in a gelatin binder on acetate base. Some sheet films may have a gelatin backcoating.

PRESERVATION ISSUES

Decay Related to Temperature and RH

- **Color image decay**[2]
- **Acetate decay.** May cause distortion, shrinkage, and brittleness. Often detected by vinegar odor (vinegar syndrome); severity can be determined with A-D Strips.
- **Mold**

Other Concerns

- **Poor air quality**
- **Outgassing.** Degrading acetate releases acidic gases that threaten nearby materials.

ISO RECOMMENDATIONS[6]

Max. temp. depends on max. RH.

14°F (-10°C) max. temp. for 50% max. RH.

27°F (-3°C) max. temp. for 40% max. RH.

36°F (2°C) max. temp. for 30% max. RH.

SIMPLIFIED STORAGE RECOMMENDATIONS[12]

COLD with 50% max. RH is less stringent than the ISO recommendation but will provide satisfactory image stability for over 300 yrs.[2] If the A-D Strip reading is 2 or greater, film should be stored at the FROZEN condition and duplicated as soon as possible.

ROOM	No
COOL	No
COLD	Good
FROZEN	Very good

Polyester Base Photographic Film

BLACK-AND-WHITE

STRUCTURE

Silver image particles in a gelatin binder on polyester base.

PRESERVATION ISSUES

Decay related to T/RH conditions

- **Silver image decay**
- **Mold**

Other concerns

- **Harmful enclosures**
- **Poor air quality**

ISO RECOMMENDATIONS[6]

Max. temp: 70°F (21°C). Max. RH: 50%

SIMPLIFIED STORAGE RECOMMENDATIONS[12]

COOL with 50% max. RH recommended to minimize possibility of silver image decay.

ROOM	Good
COOL	Good
COLD	Very good
FROZEN	Very good

COLOR

STRUCTURE

Organic dye image layers in a gelatin binder on polyester base.

PRESERVATION ISSUES

Decay Related to Temperature and RH

- **Color image decay**
- **Mold**

Other concerns

- **Harmful enclosures**
- **Poor air quality**

ISO RECOMMENDATIONS[6]

Max. temp. depends on max. RH.

14°F (-10°C) max. temp. for 50% max. RH.

27°F (-3°C) max. temp. for 40% max. RH.

36°F (2°C) max. temp. for 30% max. RH.

SIMPLIFIED STORAGE RECOMMENDATIONS[12]

COLD with 50% max. RH is less stringent than the ISO recommendation but will provide satisfactory image stability for over 300 yrs.[2]

ROOM	No
COOL	No
COLD	Good
FROZEN	Very good

CATEGORIZING YOUR ENVIRONMENT by AVERAGE TEMPERATURE

Collectively, the ISO standards for individual media contain seven different temperature recommendations. To simplify the evaluation and planning of storage conditions for mixed media collections, the MSQR divides the range of possible temperatures into four categories: ROOM, COOL, COLD, and FROZEN.

The Four Temperature Categories

Even though each of the four categories represents a range of temperatures, it is useful here to define ROOM, COOL, COLD, and FROZEN by single "anchor-point" values, as shown in Fig. 6 below. (It should be remembered that, in reality, the effect of temperature on decay rate is a continuum. The higher the temperature, the faster the decay, and vice versa.) Using Fig. 6 and data gathered through an environmental assessment, you should be able to place your storage environment in one of these four categories. It's very likely that your storage temperature is not precisely one of the four shown in Fig. 6. In this case, the following rules of thumb should help you decide where your environment fits:

1. Any environment with an average temperature at or below 32°F (0°C) can be considered FROZEN.
2. If your real-life average temperature is closer to one anchor-point temperature than another, simply apply the closer category. For example, if your storage temperature is 50°F (10°C), your environment would be considered COOL.
3. If your average temperature is about equidistant from the temperatures on either side, consider both the cooler scenario and the warmer scenario when referring to Table 3.

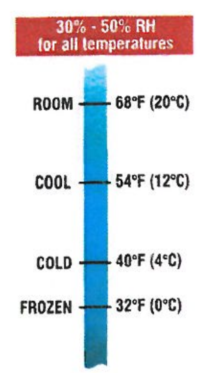


Fig. 6. The four temperature categories. In this context, ROOM, COOL, and COLD are characterized by one "anchor-point" temperature. FROZEN applies to temperatures of 32°F (0°C) and below.

SIMPLIFIED STORAGE GUIDELINES for MIXED COLLECTIONS

The impact of ROOM, COOL, COLD, and FROZEN environments can be different for different media. Before making any storage decisions, you must assess an environment's harmful or beneficial effects on the stability of the materials in your collection.

Rating Storage Suitability

The qualitative rating system defined in Table 2 is based on stability studies, ISO recommendations, and evidence gathered from the field. The terms *No, Fair, Good*, and *Very Good* were chosen to reflect the appropriateness of an environment for a specific medium. *No* means that the environment is likely to cause significant damage. *Fair, Good*, and *Very Good* can be seen as indicators of increasing benefits for material stability.

Table 2. Qualitative rating system.

QUALITATIVE RATING SYSTEM	
NO	Likely to cause significant damage.
FAIR	Does not meet ISO recommendations but may be satisfactory for extended periods.
GOOD	Comparable to ISO recommendations.[12]
VERY GOOD	Will provide an extended lifetime.

Using Table 3

Table 3 addresses two key questions: Is the current storage environment adequate? What environment does the collection really need?

Starting with the Environment

Having categorized your environment, you can determine if a media collection is safe and if other types of media can be stored in the same environment. If you have determined that your environment is ROOM, COOL, COLD, or FROZEN, you can find a qualitative rating of its suitability for the media of interest in Table 3. The table shows that most media should not be kept in ROOM conditions, as indicated by the large number of No ratings. It also indicates that all media types can be safely stored in a COLD environment. For all four environments, RH should be kept between 30% and 50%.

Starting with the Medium

Table 3 can help you determine the proper storage environment for a particular medium. It shows which environment to avoid and which environment will work for long-term preservation of that medium—useful information in planning a new storage facility or in deciding if a particular medium can be stored in an existing storage space. (See also Side 1 of the wheel.)

Which Environment for Mixed Media Collections?

The challenge of providing proper storage for collections of mixed media types can be met in two ways. You can either provide a number of special storage environments to accommodate the different types of media in your collection, or you can make an educated compromise and define one adequate environment for all materials in that collection. The color-coded rating system in Table 3 visually helps you choose a suitable environment for a particular collection. You can see at a glance that a COLD environment would be suitable for preserving a collection containing all twelve media types discussed here. COOL and FROZEN environments would also be suitable for certain mixed collections, depending on their contents. When you know what the contents of a mixed collection are, you can use Table 3 to find a "comfort zone" for long-term preservation.

What About Deteriorating Materials?

A material's current condition is a key factor in determining its storage requirements. The footnote in Table 3 points out that degrading nitrate and acetate materials need FROZEN storage for optimum stability. (Assessing the condition of acetate-base collections using A-D Strips is discussed on p. 3.)

Table 3. Suitability of environments for storage of various media types.

Storage Conditions	Glass Plates	Nitrate	Acetate		Polyester		Photo Prints		Ink Jet Prints	Magnetic Tape		CDs DVDs
			B&W	Color	B&W	Color	B&W	Color		Acetate	Polyester	
ROOM	Fair	No	No	No	Good	No	Good	No	Fair	No	No	Fair
COOL	Good	No	No	No	Good	No	Good	No	Fair	Fair	Good	Good
COLD	Very Good	Good	Good	Good	Very Good	Good	Very Good	Good	Good	Good	Good	Good
FROZEN	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good	Good	Good	No

NOTE: Degrading acetate and nitrate should be frozen. The ratings for ink jet prints reflect their susceptibility to pollutants and contaminants.

Air Quality

Proper storage for media collections should include some means to control solid and gaseous contaminants in the atmosphere.

Particulates

Particulates are very small-diameter solids that settle on surfaces in storage spaces. They can come from outside (if no filtration is provided) or be produced inside (debris from deteriorating materials or human activity). Particulates in the form of dust and grit can cause surface abrasion, and they can also be reactive toward images.

Gaseous Pollutants

These come mostly from outside sources, such as automotive exhaust and industrial processes, but they also can be produced inside by deteriorating materials or poor-quality enclosures. Pollutants released by a degrading material may affect adjacent materials in a storage area. Activities such as photocopying, general maintenance, or construction can introduce ozone, formaldehydes, ammonia, and other pollutants. Ozone and nitrogen dioxide are oxidizing pollutants that are damaging to organic dyes, silver images, and image binders.

Dealing with Pollutants

Most large commercial buildings have cloth or "bag" filters to capture particulates as they enter the building. Internally produced particulates are also reduced by these filters as the air is recirculated. Filters to remove gaseous pollutants from the outside are less common. Charcoal filters remove ozone and some other gaseous pollutants fairly efficiently, but they are less effective with nitrogen dioxide (NO_2). Potassium permanganate media can remove NO_2.

If particulate or gaseous pollutants are a problem in your institution, a plan should be made to measure the level of contamination and determine its source. As a general precaution, bag filters should be cleaned and gaseous pollutant filters should be changed regularly. Consult your facilities department about the types of systems your institution has and about the maintenance schedule.

Planning for COLD or FROZEN Storage

What Are the Options?

The equipment you choose for COLD or FROZEN storage depends on the size of your collection. Large collections might dictate the construction of insulated rooms or prefabricated walk-in chambers. Household-size refrigerators or freezers are options for small collections.

What Should the Equipment Do?

A COLD or FROZEN storage area must be able to provide not only low temperatures but also humidity control. This can be achieved with a dehumidification system or by packaging materials in moisture-proof enclosures. Both approaches are valid, but each has advantages and limitations.

Climate-Controlled Rooms

Desiccant-based dehumidification units are recommended for spaces housing medium-size or large collections, where proper storage is best provided by controlling the climate in the entire storage area. While the initial investment is large, this approach is cost-effective and convenient in the long run. Special packaging is not needed.

Refrigerators and Freezers

Household-size frost-free freezers or refrigerators are suitable for smaller media collections. With these, humidity can be managed through the use of a packaging system that will control the moisture level in the materials. While moisture-proof packaging is used to avoid the incursion of moisture into the materials, the other side of the coin is that any moisture present in the materials prior to packaging will be sealed inside. The procedure can only be successful if materials are conditioned to moderate RH before being enclosed in moisture-proof housing. Materials can be conditioned by being left for one to three weeks (time depends on media type and format) at ROOM conditions. Reclosable polyethylene freezer bags and heat-sealable bags composed of layers of aluminum foil and polyethylene and polyester have been successfully used for COLD and FROZEN storage.[2]

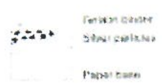
Avoiding Condensation

While there is no particular risk in moving materials directly into suitable COLD or FROZEN storage, removing them from refrigerated spaces into warmer areas incurs the risk of condensation on the materials' surface. A temperature- and RH-controlled acclimatization chamber is one solution to this problem. Another is to use an additional water-proof enclosure, such as a plastic bag or other container, in which materials can be placed for the warming-up period.[2] Such packaging is not needed for materials already in moisture-proof housings. An overnight or one-day warming period prior to using the materials is recommended.

Photographic Paper Prints

BLACK-AND-WHITE

STRUCTURE



Silver image particles in a gelatin binder on paper base. Two types of paper are used. Fiber base (the older type) is a high-quality paper with low lignin content coated with a barium sulfate (baryta) layer to impart surface smoothness. After 1968, this was largely replaced by resin-coated (RC) paper, which has a polyethylene layer on each surface. RC paper features lower water absorption and therefore faster processing speeds. It also produces flatter prints. The polyethylene layer on the image side is pigmented with titanium dioxide.

PRESERVATION ISSUES

Decay Related to Temperature and RH

- **Silver image decay**
- **Mold**

Other Concerns

- **Harmful enclosures**
- **Poor air quality**
- **Silver image decay.** Degradation of the pigmented polyethylene layer on RC papers may cause silver image decay when framed prints are exposed to light.

ISO RECOMMENDATIONS[4]

Max. temp. 61°F (16°C). Max. RH 50%

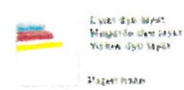
SIMPLIFIED STORAGE RECOMMENDATIONS[12]

COOL with 50% max. RH recommended to minimize possibility of silver image decay.

ROOM	Good
COOL	Good
COLD	Very good
FROZEN	Very good

COLOR

STRUCTURE



Organic dye image layers in a gelatin binder on paper base. Two types of paper are used. Fiber base (the older type) is a high-quality paper with low lignin content coated with a barium sulfate (baryta) layer to impart surface smoothness. After 1968, this was largely replaced by resin-coated (RC) paper, which has a polyethylene layer on each surface. RC paper features lower water absorption and therefore faster processing speeds. It also produces flatter prints. The polyethylene layer on the image side is pigmented with titanium dioxide.

PRESERVATION ISSUES

Decay Related to Temperature and RH

- **Color image decay**
- **Mold**

Other Concerns

- **Harmful enclosures**
- **Poor air quality**

ISO RECOMMENDATIONS[5]

Max. temp. depends on max. RH.

36°F (2°C) max. temp. for 50% max. RH.

41°F (5°C) max. temp. for 40% max. RH.

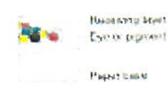
SIMPLIFIED STORAGE RECOMMENDATIONS[12]

COLD with 50% max. RH is less stringent than the ISO recommendation but will provide satisfactory image stability for over 300 yrs.[1]

ROOM	No
COOL	No
COLD	Good
FROZEN	Very good

Ink Jet Prints

STRUCTURE



The color image can consist of either dye-based or pigmented inks (the latter is generally the more stable of the two). The image may be on paper having either a swellable polymer coating, which better protects the image from the environment, or a microporous coating, which has the advantage of faster drying time. The image also may be printed on plain (uncoated) papers.

PRESERVATION ISSUES

Decay Related to Temperature and RH

- **Color image decay.** Yellowing or staining may occur.
- **Color bleeding.** More likely to occur at high humidity.
- **Mold**

Other Concerns

- **Harmful enclosures**
- **Poor air quality.** Atmospheric pollutants, such as ozone, may cause severe image deterioration, particularly with dye images on a microporous coating.

ISO RECOMMENDATIONS[6]

36°F (2°C) max. temp. for 50% max. RH.

41°F (5°C) max. temp. for 40% max. RH.

SIMPLIFIED STORAGE RECOMMENDATIONS[12]

COLD with 50% max. RH is less stringent than the ISO recommendation, but experience indicates that this should be satisfactory.

ROOM	Fair
COOL	Fair
COLD	Good
FROZEN	Very good

A CONSUMER GUIDE TO TRADITIONAL AND DIGITAL PRINT STABILITY

created by Image Permanence Institute with support from Creative Memories

We often consider the long-term stability of color prints only after it is too late to take action to save them in their original form. This eight-page guide offers insight into some of the causes of image deterioration and suggests ways to make photographic and digital color prints last longer. Available in both PDF format and printed form at www.imagepermanenceinstitute.org

A CONSUMER GUIDE TO MODERN PHOTO PAPERS

created by Image Permanence Institute with support from Sakura of America

The advent of digital photography has brought about significant changes in photo printing technologies. The characteristics of the most commonly used plain and laminated digital print paper types are discussed in this eight-page guide, along with their uses, advantages, and disadvantages. For a downloadable PDF document or printed copies, visit www.imagepermanenceinstitute.org.

Enclosures

What They Should Do, and What They Can't Do

Storage enclosures should aid in the protection, organization, and identification of collection items. Their primary function is shielding those items from dust and physical damage. Some products advertise additional protection from airborne pollutants and/or excessive humidity, although standards to evaluate their effectiveness are lacking. Enclosures also provide surfaces for labeling as well as rigidity for safe handling. However, enclosures cannot overcome deficiencies in the storage climate.

Some enclosures contain components that can harm materials stored in them and should be avoided. As temperature and humidity rise, any harmful effects from enclosures also rise. While providing new, more inert enclosures is a desirable aspect of preservation practice, improving the climate is more effective overall. Environmental improvements will simultaneously reduce risks associated with harmful enclosures, airborne pollutants, and the inherent instability of the collection materials themselves.

Enclosures should meet the requirements specified in ISO 14523 and ISO 18902.[4,5] The primary materials used to manufacture storage products are paper, paperboards, plastics, and metals. Sometimes adhesives and metal fasteners are included to create and/or reinforce structure. Requirements for each material type are given in the ISO standards.

Key Points from the ISO Standards

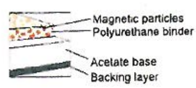
- All product components should pass the photographic activity test (PAT).
- Plastics: Do not use PVC or acetate; do use polyester, polypropylene, or polyethylene.
- Papers and paperboards: Neutral-sized, lignin-free, buffered materials are recommended (see ISO standard for buffer limits).[5]

Storage materials should be chemically and physically stable. Ideally, their life expectancies should approximate or exceed those of the materials they house. Also, their size and strength should be appropriate for the shape and weight of the objects stored in them.

Magnetic Tape

ACETATE

STRUCTURE



A recording layer of magnetic particles (iron oxides) in a polymer (polyurethane) binder on thin acetate support. The binder may also include lubricants. The back of the tape may have a coating of pigments and a polymer binder to improve durability and playback.

PRESERVATION ISSUES

Decay Related to Temperature and RH

- **Acetate decay.** May cause distortion, shrinkage, and brittleness. Often detected by vinegar odor (vinegar syndrome); severity can be determined with A-D Strips.
- **Binder degradation.** Causes uneven tape transport, tape sticking, magnetic shedding, and layer separation.
- **Mold**

Other Concerns

- **Poor air quality**
- **Outgassing.** Degrading acetate releases acidic gases that threaten nearby materials.
- **Magnetic fields.** Storage near high-intensity magnetic fields must be avoided.
- **Fragility.** Magnetic tape is thin and fragile and must be handled with care.[11]

ISO RECOMMENDATIONS[9]

Max. temp. depends on max. RH.

52°F (11°C) max. temp. for 50% max. RH.

63°F (17°C) max. temp. for 30% max. RH.

73°F (23°C) max. temp. for 20% max. RH.

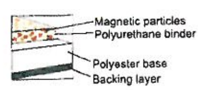
SIMPLIFIED STORAGE RECOMMENDATIONS[12]

COOL with 50% max. RH is consistent with ISO recommendation for 50% max. RH. COLD and FROZEN may cause lubricant separation with some tape formulations. If the A-D Strip reading is 2 or greater, tape should be stored at the FROZEN condition and copied as soon as possible.

ROOM	No
COOL	Fair
COLD	Good
FROZEN	Good

POLYESTER

STRUCTURE



A recording layer of magnetic particles (iron oxides, metalic iron or chromium dioxide) and pigments in a polymer (polyurethane) binder on thin polyester support. The binder may also include lubricants. The back of the tape may have a coating of pigments and a polymer binder to improve durability and playback.

PRESERVATION ISSUES

Decay Related to Temperature and RH

- **Binder degradation.** Causes uneven tape transport, tape sticking, magnetic shedding, and layer separation.
- **Mold**

Other Concerns

- **Poor air quality**
- **Magnetic fields.** Storage near high-intensity magnetic fields must be avoided.
- **Fragility.** Magnetic tape is thin and fragile and must be handled with care.[11]

ISO RECOMMENDATIONS[9]

Max. temp. depends on max. RH.

52°F (11°C) max. temp. for 50% max. RH.

63°F (17°C) max. temp. for 30% max. RH.

73°F (23°C) max. temp. for 20% max. RH.

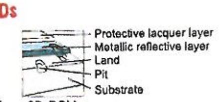
SIMPLIFIED STORAGE RECOMMENDATIONS[12]

COOL is consistent with ISO recommendation for 50% max. RH. COLD and FROZEN may cause lubricant separation with some tape formulations.

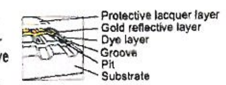
ROOM	No
COOL	Good
COLD	Good
FROZEN	Good

CDs and DVDs

STRUCTURE



CD-ROM



CD-R

CDs have a complex structure and are made up of at least three layers: a polycarbonate support, a reflective aluminum or gold layer, and a protective coating. Recordable CDs (CD-Rs) and magneto-optical (MO) discs have an additional laser-sensitive layer coated on the support. DVDs are even more complex, consisting of two CDs bonded with an adhesive. The polycarbonate supports form the outside layers of the laminate. Different DVD formats have different layer structures.

PRESERVATION ISSUES

Decay Related to Temperature and RH

- **Loss of disc integrity.** Under adverse storage, possible defects are layer separation, lack of planarity, cracking, and pinholes. Large and rapid temperature and RH fluctuations can be particularly detrimental.
- **Corrosion.** May occur due to high RH.
- **Mold**

Other Concerns

- **Poor air quality.** Pollutants can cause corrosion of the metallic reflective surface.
- **Magnetic fields.** MO discs must not be stored near a high-intensity magnetic field.
- **Light exposure.** CD-R discs must not be subjected to prolonged light exposure.

ISO RECOMMENDATIONS[10]

73°F (23°C) for 50% max. RH.

Storage of discs below 14°F (-10°C) should be avoided.

SIMPLIFIED STORAGE RECOMMENDATIONS[12]

COOL and COLD considered optimum. FROZEN not recommended because of concerns about layer separation.

ROOM	Fair
COOL	Good
COLD	Good
FROZEN	No

MEDIA SUPPORT CHRONOLOGY

The life expectancy of a recording medium depends in part on the stability of the material supporting the recording layers. Because these support materials differ widely in stability, being able to distinguish them is key to knowing how long certain portions of your collection might last. In the context of collection preservation, a nondestructive identification procedure is preferred and is often required. Table 4 and the Media Support Chronology (Side 2 of the wheel) offer information to assist in identifying the principal support materials for film and tape media.

Using the Media Support Chronology and Table 4

Nine categories of recording media are presented on Side 2 of the wheel. Three windows, representing the three plastic support materials most commonly used with these media, reveal the periods of widest use for each medium/support combination.* If you can place a film or tape in one of the media categories and you know its age, you will be able to determine its support material. If, for example, you know that a roll of microfilm dates from 1935, you will learn by looking at the wheel that it is most likely on acetate support.

The life expectancy table on Side 2 tells how long several of the most common film supports can be expected to remain in useful condition when stored at 68°F (20°C) and 50% RH.

Format can be a clue to the identity of a film or tape support. Table 4 lists formats, dates of introduction, and types of support for a selection of media.

Table 4. Chronology of selected media formats.

MEDIUM	FORMAT	DATE OF INTRODUCTION	SUPPORT
	28mm	1912	
	9.5mm, 16mm	1920s	Acetate
AMATEUR MOVIE FILM	8mm	1932	
	Super-8 (Kodak)	1965	
	Single-8 (Fuji)	1965	Polyester
		1890s	Nitrate
SHEET FILM	Various formats (2¼ x 3¼, 4 x 5, 8 x 10, etc.)	Late 1920s	Acetate
		Mid-1960s	Polyester
MAGNETIC TAPE, AUDIO	Reel-to-reel and, later, cassettes	1934	Acetate
		1963	Polyester
	2" quad	1956	
	¾" U-Matic	1971	
MAGNETIC TAPE, VIDEO	VHS	1976	Polyester
	Betacam SP	1986	
	D1	1986	
	16mm, 35mm	Late 1920s	Acetate
MICROFILM	Microfiche	1935	
	All formats	1970s	Polyester

Film Supports

Nitrate

When photographic film was first introduced in the 1890s, cellulose nitrate was the only available plastic. It had many of the necessary properties, but it also had the serious disadvantage of high flammability. Nitrate was gradually replaced by the cellulose acetate family.

Nitrate film produced after 1930 is usually edge-marked "NITRATE." The observable signs of decay that are unique to nitrate film can provide clues to its identity as well. See Nitrate-Base Photographic Film on p. 3.

The stability of nitrate base is highly variable. This support was last manufactured over 50 years ago, and the least stable specimens already have been lost. However, some cellulose nitrate supports are more stable than the more recent cellulose acetate materials.

Acetate

Several modifications of cellulose acetate were manufactured after the 1920s. When cellulose triacetate became available in 1949, cellulose nitrate was discontinued.

Acetate film is usually edge-marked with the word "SAFETY." When held up to a light source and viewed edge-on, acetate photographic film in roll form transmits very little light compared to polyester, which also has the "SAFETY" marking.

Like nitrate film, acetate film displays unique signs of decay, which can help in identification. For more detail, see Acetate-Base Photographic Film (p. 4.)

Polyester

Polyester support was introduced in the mid-1950s. The original polyester support was polyethylene terephthalate. In 1996, a modification, polyethylene naphthalate, was marketed for amateur roll film.

Polyester film is easily identified by the color fringes that appear when it is viewed by transmitted light through two polarized plastic sheets.[1] As mentioned, a roll of polyester photographic film transmits more light than acetate when held up to a light source and viewed edge-on. Shaking a single sheet of polyester makes a "tinny" sound.

Polyester has markedly greater strength and chemical stability than nitrate or acetate.

Magnetic Tape Supports

Magnetic tape need not be transparent, but it is very thin and must withstand the physical stresses of use. Polyvinyl chloride was used for early magnetic tapes. Between 1934 and 1963, cellulose acetate materials were employed, primarily for audio tape. Since 1956 polyester has been the choice for video and computer tape because of its greater strength.

The same light transmission method used for distinguishing acetate and polyester photographic film can be used for magnetic tape; in this case, however, the behavior of the two materials is reversed. Acetate tape rolls transmit more light than polyester tape rolls when held up to a light source and viewed edge-on.

Magnetic tape on acetate base is subject to the same types of decay as acetate photographic film. Polyester magnetic tape is much more stable.

*Exact dates cannot be given for every material. In some cases, historical records are no longer available. The choice of support materials sometimes varies with manufacturer and geographic location. Some plastics are not included on the wheel because they had limited use—for example, polyester base for amateur movie film, polycarbonate for aerial film, and polyvinyl chloride and polystyrene for graphic arts film.

GLOSSARY

Acetate: A transparent plastic base for photographic film made by treating cellulose with acetic acid. This term is used for various modifications of cellulose acetate, e.g., cellulose diacetate, cellulose triacetate, cellulose acetate propionate, and cellulose acetate butyrate.

Acetate decay: Vinegar syndrome. Degradation of cellulose acetate film base that may cause distortion, shrinkage, and brittleness, often detected by a vinegar odor. The severity of decomposition can be determined using A-D Strips.

A-D Strips: Indicator papers, manufactured by IPI, which change color when acetic acid is produced by degrading cellulose acetate film base.

Baryta: A layer of barium sulfate in gelatin applied to the surface of photographic paper base to provide opacity, smoothness, and brightness.

Base: The support of an imaging or recording material on which the recording layer is coated.

Binder: The polymer that contains recording or imaging particles. For example, gelatin is the binder for silver image particles in photographic media.

Binder degradation: Decomposition of the polymer layer that contains the recording material. (See also *Magnetic shedding*.)

Buckling: Distortion or lack of flatness. This may be caused by chemical degradation, shrinkage, or flow. (See *Distortion*.)

Channeling: Buckling of the emulsion caused by base shrinkage.

Color balance shift: A change in the overall tone of color images.

Color bleeding: Movement of the colorant in color images, either laterally into adjacent areas in the image plane or outside the image plane to a contacting sheet.

Color fading: A decrease in image density that results in overall fading.

Color image decay: Can be manifested as color fading, color balance shift, yellowing, or color bleeding.

Crossed polarizers: Polarized sheets that are oriented at right angles to each other and used to depict the orientation of polyester molecules. Bands of color appear when polyester support is placed between crossed polarizers.

Delamination: Separation of individual layers of a laminated material, e.g., separation of emulsion from the glass base in photographic plates or separation of individual layers in optical discs.

Distortion: Lack of flatness of a material.

Emulsion: The image-forming layer of photographic films, papers, and plates.

Gelatin: A protein obtained from naturally occurring collagen. Used as a binder for the image layer of photographic materials.

Glass deterioration: Degradation of glass supports caused by exposure to high humidity. May result in a hazy appearance or layer separation in photographic glass plates.

Harmful enclosure: A folder, envelope, sleeve, box, or other container that causes silver image decay and/or staining of binder and supports.

I3A: The International Imaging Industry Association in Harrison, New York, which facilitates the development of media storage and other technical standards for the imaging industry.

ISO: The International Standards Organization, in Geneva, Switzerland, which publishes internationally agreed-upon norms and best practices for a variety of industrial products and processes.

Layer separation: The partial or complete separation of a laminate into its constituent layers. (See also *Delamination*.)

Life expectancy (LE): A rating for the expected longevity of recording materials and associated retrieval systems.

Magnetic shedding: Degradation of the binder of magnetic tape, which results in loss of magnetic oxide particles during storage or playback.

Microspots: Small colored spots, usually red or orange, caused by localized oxidation of black-and-white images.

MO disc: A digital storage medium that uses magneto-optical technology.

Mold: Fungus that grows on polymer or organic materials exposed to high humidity; causes material degradation.

Nitrate: A transparent plastic base that was used for photographic film. Obtained from the treatment of cellulose with nitric acid.

Nitrate decay: Degradation of cellulose nitrate film base that may cause yellowing, buckling, film distortion, and corrosion of metal cans. Can also cause gelatin binder to become soft or sticky or to disintegrate.

Outgassing: The tendency of some materials, e.g., acetate and nitrate film bases, to give off harmful vapors as they decay.

PAT: Photographic activity test, which evaluates chemical or photographic interactions between enclosure materials and photographic images, as described in ISO 14523.

Polarizer: A sheet, containing oriented particles, that transmits light that vibrates in only one direction.

Polyester: A transparent plastic base for photographic film and magnetic tape that is composed of a polymer of ethylene glycol and terephthalic (or naphthalene dicarboxylic) acid. It is very strong and stable.

RC: A resin coating applied to the surface of photographic paper base to speed processing and drying.

RH: Relative humidity, the amount of water vapor in the air expressed as a percentage of the maximum amount that the air could hold at the given temperature.

Sheet film: A single piece of flat (non-roll) film found in various formats, such as 4" x 5" or 5" x 7".

Silver image decay: A defect of a black-and-white silver image, which can be manifested as microspots, silver mirroring, or overall image discoloration.

Silver mirroring: Oxidation of black-and-white images, in which the image silver migrates to the surface, creating a mirror-like appearance.

Support: The glass, plastic, or paper base on which the image layers of photographic film, prints, or magnetic tape is coated.

System obsolescence: A problem associated with machine-readable images, data, or sound recordings, whereby the information can be recovered only by using hardware or software that is obsolete.

Tape deformation: Distortion of magnetic tape resulting in lack of flatness. (See also *Distortion*, *Buckling*.)

Vinegar syndrome: The degradation of acetate base, which is characterized by the odor of vinegar (acetic acid). (See *Acetate decay*.)

Yellowing: Discoloration that affects a color image or, in earlier color processes, the white border of a print.

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The IPI Storage Guide for Acetate Film and the Storage Guide for Color Photographic Materials can be purchased from the Image Permanence Institute (www.imagepermanenceinstitute.org). The ISO standards can be purchased from the International Organization for Standardization, Case Postale 56, CH-1211, Geneva 20, Switzerland (www.iso.org).

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