IPI Media Storage quick reference

Negatives
Prints
Tapes
CDs
DVDs

2nd edition

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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.

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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.

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.

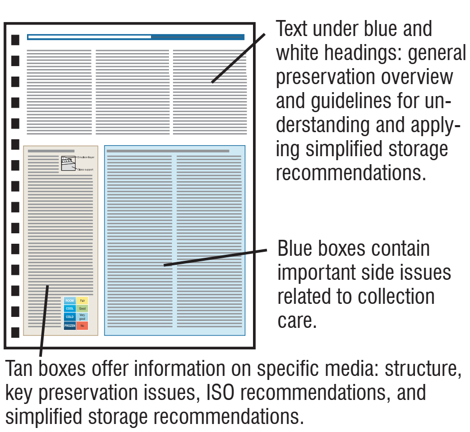


Fig. 1. Guide to navigating the MSQR.

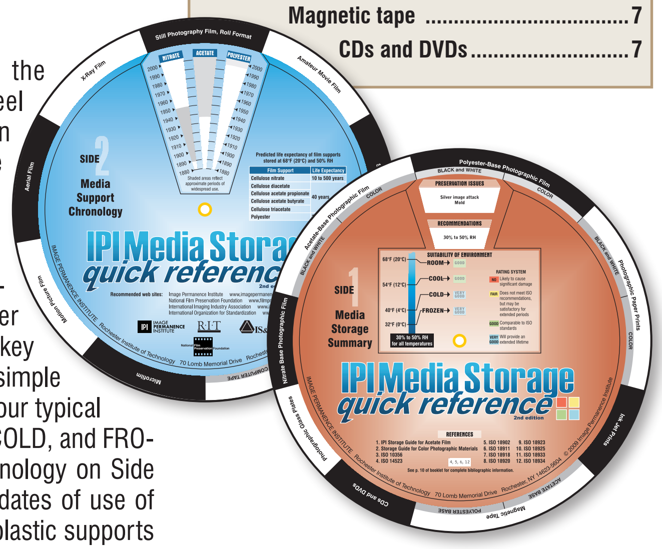


Fig. 2. The Media Storage Summary is on Side 1 of the MSQR wheel. The Media Support Chronology is on Side 2.

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

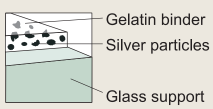
Mechanical forms of decay are related to the changes in size and shape of water-absorbing materials such as cellulosic plastic film supports or the gelatin binder in photographic materials. RH is the environmental variable that determines how much water is absorbed into collection objects. When the RH 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.

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.

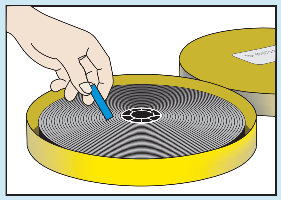


Fig. 4. Testing with A-D Strips.

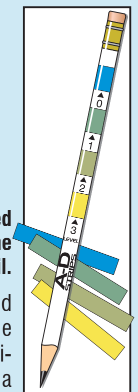


Fig. 5. Strip color is compared to the color scale printed on the accompanying pencil.

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.

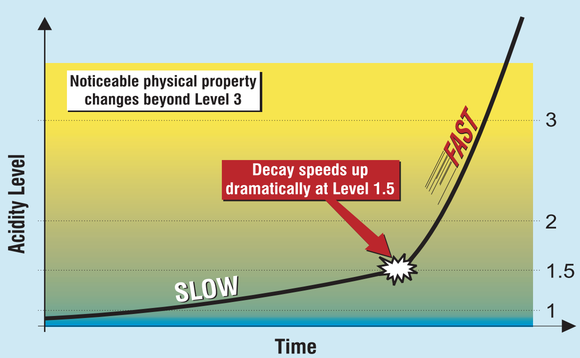


Fig. 3. Relationship between A-D Strip levels, film acidity, and film condition.

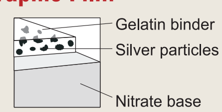
Should Degraded Nitrate and Acetate Film Be Segregated?

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.

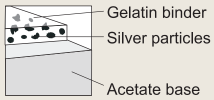
ROOM	No
COOL	No
COLD	Good
FROZEN	Very good

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]

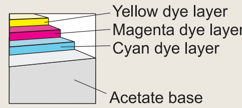
COLD with 50% max. RH is similar to the ISO recommendation. If the A-D Strip reading is 2 or greater, film should be stored at the FROZEN condition and duplicated as soon as possible.

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.

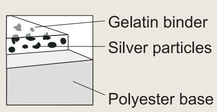
ROOM	No
COOL	No
COLD	Good
FROZEN	Very good

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]

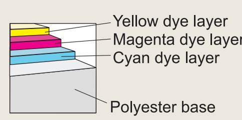
COOL with 50% max. RH recommended to minimize possibility of silver image decay.

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.

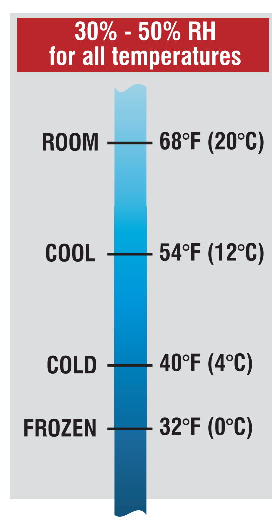


Fig. 6. The four temperature categories. In this context, ROOM, COOL, and COLD are characterized by one "anchor-point" temperature. FROZEN applies to temperatures of 32°F (0°C) and below.

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]

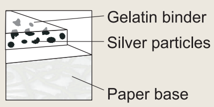
Avoiding Condensation

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[8]

Max. temp: 61°F (16°C). Max. RH: 50%.

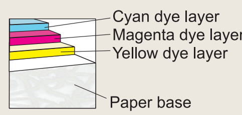
SIMPLIFIED STORAGE RECOMMENDATIONS[12]

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[8]

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.

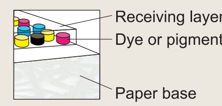
SIMPLIFIED STORAGE RECOMMENDATIONS[12]

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

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[8]

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

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

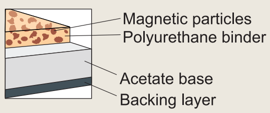
- All product components should pass the photographic activity test (PAT).
- Plastics: Do not use PVC or acetate; do use polyester, polypropylene, or polyethylene.
- Papers and paperboards: Neutral-sized, lignin-free, buffered materials are recommended (see ISO standard for buffer limits).[5]

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.

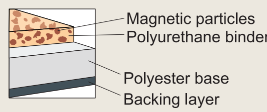
SIMPLIFIED STORAGE RECOMMENDATIONS[12]

ROOM	No
COOL	Fair
COLD	Good
FROZEN	Good

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.

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.

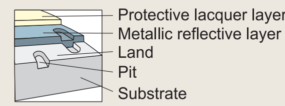
SIMPLIFIED STORAGE RECOMMENDATIONS[12]

ROOM	No
COOL	Good
COLD	Good
FROZEN	Good

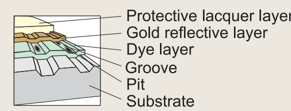
COOL is consistent with ISO recommendation for 50% max. RH. COLD and FROZEN may cause lubricant separation with some tape formulations.

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]

ROOM	Fair
COOL	Good
COLD	Good
FROZEN	No

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

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

*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.

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.

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.

REFERENCES

1 J. M. Reilly, *IPI Storage Guide for Acetate Film* (Rochester, NY: Image Permanence Institute), 1996.

2 J. M. Reilly, *Storage Guide for Color Photographic Materials* (Albany, NY: The University of the State of New York, New York State Education Department, New York State Library, The New York State Program for the Conservation and Preservation of Library Research Materials), 1998.

3 *ISO 10356 Cinematography: Storage and handling of nitrate-base motion-picture films* (Geneva: International Organization for Standardization), 1996.

4 *ISO 18916 Imaging materials: Processed imaging materials—Photographic activity test for enclosure materials* (Geneva: International Organization for Standardization), 2007.

5 *ISO 18902 Imaging materials—Processed photographic films, plates and papers—Filing enclosures and storage containers* (Geneva: International Organization for Standardization), 2001.

6 *ISO 18911 Imaging materials—Processed safety photographic films—Storage practices* (Geneva: International Organization for Standardization), 2000.

7 *ISO 18918 Imaging materials—Processed photographic plates—Storage practices* (Geneva: International Organization for Standardization), 2000.

8 *ISO 18920 Imaging materials—Processed photographic reflection prints—Storage practices* (Geneva: International Organization for Standardization), 2000.

9 *ISO 18923 Imaging materials—Polyester-base magnetic tape—Storage practices* (Geneva: International Organization for Standardization), 2000.

10 *ISO 18925 Imaging materials—Optical disc media—Storage practices* (Geneva: International Organization for Standardization), 2002.

11 *ISO 18933 Imaging materials—Magnetic tape—Care and handling* (Geneva: International Organization for Standardization), 2006.

12 *ISO 18934 Imaging materials—Multiple media archives—Storage environment,* 1st ed. (Geneva: International Organization for Standardization), 2006; 2nd ed. to be published in 2010.

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).

Acknowledgements

This publication was made possible through a project funded by The Andrew W. Mellon Foundation and managed by the National Film Preservation Foundation (www.filmpreservation.org). The National Endowment for the Humanities, Division of Preservation and Access, funded much of the research underlying this publication, which is the result of the combined efforts of the Image Permanence Institute staff. Major contributors were Jean-Louis Bigourdan, Daniel Burge, James Reilly, Karen Santoro, and Edward Zinn. Many thanks go to Annette Melville of NFPF for her enthusiastic support and also to the students and staff of the L. Jeffrey Selznick School of Film Preservation at the George Eastman House for their valuable input.

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