6. Storage

Improving storage is the single most important step that institutions can take to protect their film collections. This chapter outlines the benefits brought by cold and dry storage and suggests options available to cultural repositories. It also discusses film containers, nitrate segregation, and other storage issues particular to the motion picture. Cold and dry storage wins preservationists a measure of control over the film decay process and buys time for preservation copying.[1]

6.1 IPI Recommendations for Film Materials

Temperature and moisture are the two key factors affecting the rate of film deterioration. Fresh acetate film stored at a temperature of 65°F and 50% RH (relative humidity) will last approximately 50 years before the onset of vinegar syndrome. Just reducing the temperature 15°, while keeping the humidity at the same level, delays the first signs by 150 years.[2] Low temperature and low relative humidity levels slow chemical decay and increase the stability of motion picture film.

For nearly two decades the Image Permanence Institute (IPI) at the Rochester Institute of Technology has studied the effect of light, heat, pollutants, and humidity on film and paper decay and developed tools to diagnose and measure these problems. In conjunction with this guide, IPI has produced the *IPI Media Storage Quick Reference*, a publication bringing together information on storing photographs, audiotapes, videotapes, CDs, and DVDs, as well as motion picture film. Recognizing that many repositories house these media together, IPI has developed climate condition charts to enable preservationists to choose storage solutions that maximize benefits to a fuller range of their collections. This section distills some of the key recommendations for motion picture materials. Consult the IPI Web site (www.rit.edu/ipi) and the *IPI Media Storage Quick Reference* for more detailed information.

The IPI charts reflect the recommendations of the International Organization for Standardization (ISO). The ISO publishes standards defining the environmental conditions that promote the stability of specific media. The IPI charts present the

1. This chapter is drawn largely from the following sources: Peter Z. Adelstein, *IPI Media Storage Quick Reference* (Rochester, NY: Image Permanence Institute, Rochester Institute of Technology, 2004); James M. Reilly, *Storage Guide for Color Photographic Materials: Caring for Color Slides, Prints, Negatives, and Movie Films* (Albany, NY: University of the State of New York, New York State Education Department, New York State Library, New York State Program for the Conservation and Preservation of Library Research Materials, 1998); *IPI Storage Guide for Acetate Film: Instructions for Using the Wheel, Graphs, and Tables* (Rochester, NY: Image Permanence Institute, Rochester Institute of Technology, 1993); the Kodak Web site, www.kodak.com; and Film Forever: The Home Film Preservation Guide, www.filmforever.org.

2. As estimated on the wheel in the *IPI Storage Guide for Acetate Film*. The film acidity at the onset of vinegar syndrome measures approximately 1.5 on an A-D Strip (see 2.6).

TABLE 8. HOW TEMPERATURES AFFECT FILM MATERIALS
(when RH is between 30% and 50%)

Film Material	**Room** 68°F (20°C)	**Cool** 54°F (12°C)	**Cold** 40°F (4°C)	**Frozen** 32°F (0°C)
Nitrate film*	Likely to cause significant damage	Likely to cause significant damage	Meets ISO recommendations	Provides extended life
Acetate film*	Likely to cause significant damage	Likely to cause significant damage	Meets ISO recommendations	Provides extended life
Polyester film	B&W: May be OK Color: Causes significant damage	B&W: Meets ISO recommendations Color: Causes significant damage	B&W: Provides extended life Color: Meets ISO recommendations	Provides extended life
Videotape, magnetic sound track, and prints with magnetic sound track	May cause significant damage	Acetate: May be OK Polyester: Meets ISO recommendations	Acetate: Meets ISO recommendations Polyester: May be OK	May cause significant damage
DVDs	May be OK	Meets ISO recommendations	Meets ISO recommendations	May cause significant damage

Source: *IPI Media Storage Quick Reference.*

*Nitrate and acetate base film should be frozen if there are signs of decay.

ISO recommendations in a format that is easy to apply in collection planning. They simplify the temperature data into four categories, each characterized by a single midpoint temperature value: ROOM (68°F), COOL (54°F), COLD (40°F), and FROZEN (32°F). Climate conditions are rated on a four-level scale based on their effects on the stability of materials: NO (likely to cause significant damage), FAIR (does not meet ISO standards but may be OK), GOOD (meets ISO recommendations), and VERY GOOD (provides extended life). In reality, of course, the relationship of temperature to the decay rate of collection materials is a continuum. Generally the lower the temperature, the slower the decay.

Table 8 summarizes how temperature affects the longevity of motion picture materials when the relative humidity remains between 30% and 50%.[3] To evaluate how your storage conditions measure up, you will need to know your film storage area's average temperature and confirm that its relative humidity is generally between 30% and 50% (see 6.3).

3. Relative humidity is the ratio of the amount of water in the air to the maximum air can hold at that given temperature. The higher the RH, the more moisture will be present in a film. With high relative humidity levels, film decay advances more rapidly and mold is more likely to grow.

If you are unable to gather this information by computer, you can use an inexpensive thermohygrometer, which measures both temperature and relative humidity.[4] Once you have the temperature and relative humidity readings, pick the category that is closest to the average of your storage area and look down that column. For example, if your storage temperature is 45°F, your conditions would be considered cold. If your average temperature is midway between two categories, your environment will share the characteristics of both.

For most film materials IPI finds that frozen temperatures, if RH is held between 30% and 50%, extend useful life. However, DVDs and materials having a magnetic layer—magnetic sound track and videotape—may be damaged under freezing conditions. For mixed collections that include all types of film-related media, cold (40°F) seems preferable.

Composite prints with magnetic sound tracks present a perplexing case. If a print in advanced decay is frozen to conserve the film base, there is a risk of damage to the sound track. However, if the film base succumbs to vinegar syndrome, the entire artifact is lost. Until more scientific research has been completed on magnetic track damage, IPI recommends considering the film base as the determining factor and freezing the original.

Table 8 also points to the damage caused by room-temperature storage. Room temperatures accelerate the chemical decay of magnetic tape and nitrate, acetate, and color films. Just lowering the temperature to cool (54°F), while falling short of ISO standards for most film materials, brings a significant improvement.

IPI has developed a tool to help you estimate how long newly processed film materials might last under your present storage conditions. The Preservation Calculator, available on the IPI Web site, illustrates how storage conditions influence the decay rate of collection materials. It shows how temperature and relative humidity work together to speed or slow deterioration.

To use the calculator, download the program and input the temperature and relative humidity of your storage area by using the sliding gauge. The calculator will estimate the number of years before your films exhibit significant signs of deterioration. The calculator also approximates the risk of mold. Mold spores will not germinate if the relative humidity is below 65%. Light and air circulation also discourage mold growth.

6.2 Improving Film Storage Conditions

If your storage environment does not adequately protect film materials, your organization has several ways to make improvements. The choice depends on collection size, availability of resources, frequency of use, and institutional commitment to preservation.

4. A simple thermohygrometer can be purchased from a conservation supply house for under $50. More complex instruments with a higher degree of accuracy cost more. Some of the supply houses listed in appendix D carry these devices.

Cold storage vault, set at 40°F and 30% RH, with films shelved horizontally.

Cold storage vaults. For large and medium-size collections the best solution is often an insulated cold storage room with humidity control and air circulation. IPI recommends a desiccant-based dehumidification unit that will control humidity for the entire storage area. With this arrangement, no additional desiccants are needed in the packaging of individual films (see 6.6). It is important that the walk-in cold room be used solely for storage and not do double duty as work space. Many repositories protect the security of their cold storage areas with a locked door or security system.

Refrigerators and freezers. Small media collections can be accommodated in off-the-shelf frost-free freezers or refrigerators. A major challenge in using freezers and refrigerators is protecting film from high humidity during storage. This can be achieved by careful packaging. (The critical issue of protecting films from condensation when they are removed from a freezer or refrigerator is discussed in 6.4.)

Freezing to slow advanced vinegar syndrome

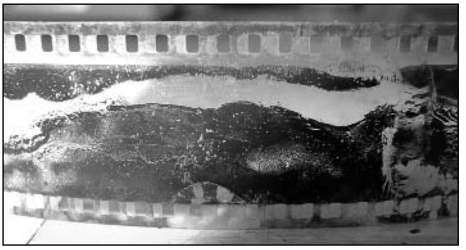
Acetate films at the A-D Strip level of 2 (see 2.6) are at a critical threshold in the decay process. At this point the chemical deterioration rapidly accelerates and the artifact soon becomes unusable. Acetate films in advanced decay should be copied immediately or frozen until duplication is feasible.

Film Forever: The Home Film Preservation Guide (www.filmforever. org) illustrates the steps in packaging a film for refrigeration or freezing. To protect each film, you will need a rigid film container[5] and either resealable polyethylene freezer bags or heat-sealable laminate bags made of layers of aluminum foil and polyethylene or layers of aluminum foil, polyester, and polyethylene. The laminate bags provide better protection, but for convenience, let's assume you are using heavy-duty zip-sealed freezer bags.

Sealed film bags in freezer. Frozen storage is not advised for reference prints or frequently consulted materials.

Start by removing the lid from the film can and bringing the film and packaging materials to room temperature and a relative humidity not exceeding 60%. If the film and packaging have been kept at

5. The rigid container provides physical protection for the film in the freezer.



Storing film on the floor or in areas prone to water seepage, such as basements, can result in water damage. Here water has washed away the emulsion from deteriorated nitrate film.

PLACES *NOT* TO STORE FILM

1. Basements (often have high humidity) or on the floor
2. Attics (hot in summer and have fluctuating temperature throughout the year)
3. In direct sunlight or next to a window
4. Near heaters, radiators, or sprinklers
5. Near chemical, paint, or exhaust fumes
6. For magnetic sound tracks, near magnetic fields such as those produced by heavy-duty electrical cables, electrical equipment, and transformers

these conditions for some time, you can start work. If the film has been in hot and humid conditions, it might take several weeks to reach the acceptable relative humidity threshold.[6]

Once the film has been conditioned to room temperature and a relative humidity not exceeding 60%, close the film can and seal it with tape. Place the can in the bag, press out the extra air, close the seal, and secure it with tape. Be sure to label the bag clearly so that the title can be read without reopening. Then repeat the operation to double-bag the can, securing the final seal with tape. The film is now ready for refrigeration or freezing.

OFF-SITE STORAGE. A third option is to rent storage space from a commercial vendor. A number of North American firms operate film storage facilities—some

QUESTIONS TO ASK POTENTIAL STORAGE VENDORS

1. What is the temperature and relative humidity? At what intervals are these environmental conditions monitored and corrected?
2. What types of materials will be stored in the same storage room as my films?
3. When films are needed, are they paged or retrieved self-service style?
4. If the films are paged, what is the staging procedure for removing and returning films to storage?
5. What level of security is practiced?
6. Do you have back-up generators in the case of power failure?
7. Do you have a disaster plan?
8. How is storage space priced?

6. For a discussion of the dangers of condensation and the steps to control it, see Reilly, *Storage Guide for Color Photographic Materials*, 34–44.

underground and others in climate-controlled buildings. Most Hollywood studios use commercial facilities to store back-up materials in remote locations. By geographically separating film materials, they gain extra protection in case one location is destroyed by flood, earthquake, fire, or other disaster. Remote storage is viable only for materials that are infrequently consulted.

Sometimes organizations with small film collections arrange to store their originals and masters with larger nonprofit or public film repositories. Some organizations have also formed consortia and pooled resources to develop group storage space.

6.3 Monitoring the Storage Environment

Maintaining good storage conditions requires vigilance. IPI recommends continuous monitoring of the temperature and relative humidity either through remote sensors connected to a computer system or electronic data loggers linked to a personal computer.[7] Data loggers recording both temperature and relative humidity can be purchased for under $100. Some specialized systems also check for air contaminants and pollutants. You can also take regular temperature and relative humidity readings of your storage area using a thermohygrometer or a thermometer and a hygrometer. The manual approach requires a greater investment of staff time.

Coping with power failure

Freezers and refrigerators will slowly heat up during a blackout. In this situation, avoid opening the door, and allow the films to come gradually to room temperature. Films protected in moisture-proof housing should not be harmed by melting ice. Generally if the door has remained closed, the films can be returned directly to the original conditions when the power returns.

By analyzing and using the data obtained through these tools, your organization can assure that the temperature and humidity are maintained within an acceptable range and protect against seasonal fluctuations. Small spikes in temperature and relative humidity, such as the ones caused by a short power failure, do not pose a threat to media collections. In general it is more important to keep the average long-term temperature and relative humidity within acceptable bounds than to maintain them at a constant level.

6.4 Removing and Returning Films to Storage

Sometimes films in cold storage are needed for public service or preservation work. When moving films from a cold or frozen environment to room temperature, steps must be taken to protect the materials from condensation. This can be accomplished by either of two methods.

7. Information about IPI's Climate Notebook software and Preservation Environment Monitor is available on the IPI Web site. For a comparison of the Kiwi, ACR, and Onset data loggers, see Judy Ritchie, "Temperature, Humidity, and Light: A Comparison of Data Loggers," under "Newsletters" at www.onsetcomp.com.

Some organizations move the needed film to an environmentally controlled "staging" room set at a temperature and humidity that will prevent condensation on film. The temperature and humidity levels for this room should be determined in consultation with your institution's engineer or environmental planner.

An alternative approach is to place the film in a moisture-proof container before removal from the colder environment. Any condensation will then take place on the outside of the container and not on the film. The container may be as simple as a heavy-duty zip-sealed freezer bag.

The length of the warming time depends on the film mass. A large roll of 35mm film will require more time to acclimate to the new conditions than a tiny reel of 8mm film. For ease of implementation, organizations generally have across-the-board staging procedures that they apply to all film gauges and lengths. George Eastman House, for example, keeps its cold vaults at 40°F and 30% RH and its staging room at 55°F and 50% RH. It has a policy of allowing films to acclimate for at least 24 hours before transfer to work areas. This minimum warming time is suitable for most archival settings.

If the relative humidity has remained under 60%, returning films to cold storage is relatively straightforward and can be accomplished without reverse staging. For frozen films follow the procedures outlined in 6.2.

6.5 Storing Nitrate Film

Because it is a potential fire hazard, cellulose nitrate film has special storage needs. The National Fire Protection Association (NFPA) issues guidelines for the construction of cabinets and vaults for storing nitrate-based motion pictures. For small quantities—5 to 150 rolls (25 to 750 pounds), it recommends steel cabinets with a built-in sprinkler system and outside venting to allow the escape of gases produced by decomposition.[8] Larger-scale storage requires special compartmentalized vaults. For nitrate film, the ISO standards recommend a maximum temperature of 36°F and relative humidity between 20% and 30%.

Many localities require compliance with NFPA guidelines. It is worth checking with your fire department regarding local policy.

A few reels of nitrate film can be stored in a frost-free freezer. Most organizations, however, prefer to arrange for off-site commercial storage of nitrate motion picture

8. See National Fire Protection Association, *Standard for the Storage and Handling of Cellulose Nitrate Film*, NFPA 40 (Quincy, MA: National Fire Protection Association, 2001), which can be purchased online at www.nfpa.org. See also *Safe Handling, Storage, and Destruction of Nitrate-Based Motion Picture Films*, Kodak Pub. H-182 (Rochester, NY: Eastman Kodak Company, 2003), also available at www.kodak.com, and Christine Young, *Nitrate Films in the Public Institution*, Technical Leaflet 169 (Nashville: American Association for State and Local History, 1989), originally published in *History News* 44 (July/August 1989).

films or transfer to archives with specialized facilities. Whenever possible, nitrate film should not be stored in storage vaults with safety film. Once nitrate film has reached the point where it cannot be copied (see 2.6), Kodak recommends its disposal by a federally authorized hazardous waste facility.

6.6 What Makes a Good Film Container?

Film containers—boxes or cans—should be convenient to use and should protect the film from dust and physical damage. As the physical unit for organizing collections, containers should also provide a rigid surface for shelving and give some measure of fire and water protection. Some also give additional protection in shipping.

Film containers come in different sizes and designs, some vented to allow air circulation.

Manufacturers make film containers from archival cardboard, plastic, and metal. The ISO publishes standards for enclosures for photographic materials. These recommend that plastic cans be made of polypropylene or polyethylene. Cardboard boxes should be either neutral or buffered and composed of lignin-free materials. Cans made of noncorroding metal are also acceptable. Also, containers should not include glues or additives that might have a chemical reaction with the film, as measured by IPI's Photographic Activity Test.[9]

Sealing film containers

Should preservationists seal film containers or vent them? Much depends on how the film is stored.

If the film is kept at room temperature, a tightly closed container will prevent the escape of acetic acid and can accelerate vinegar syndrome. At room temperature a sealed container will also speed deterioration of nitrate film. As temperature decreases, however, the chemical reaction slows and venting makes less difference.

When storing films in frost-free freezers, an airtight seal is necessary to protect film from the incursion of moisture (see 6.2). Also, seal the can when using molecular sieves.

9. The potential for interaction between photographic materials and their enclosure is measured by the Photographic Activity Test, developed by IPI and accepted as a worldwide standard. The test determines if chemical ingredients in the enclosure will affect the photographic materials. For more information see www.rit.edu/ipi.

USING MOLECULAR SIEVES

Molecular sieves are desiccants placed in a sealed film can to adsorb acetic acid vapors and moisture. The tiny packets are placed between the film roll and the interior wall of the can. The packets should be replaced when they have reached their maximum adsorption level. This process takes about two years at room temperature. As the storage temperature decreases so does the marginal improvement brought by molecular sieves. For diagrams illustrating the use of this product, search "Acid Scavenger," on the Kodak Web site, www.kodak.com.

For most nonprofit and public institutions, molecular sieves are too expensive and time-consuming to use throughout a film collection. Organizations generally employ them selectively.

The cans or boxes you choose will depend on your institution's storage conditions and funding. Whatever type you select, make sure that the container is chemically inert, physically stable, and expected to last as long as the film it houses. The enclosure's size should match that of the film. Always stack containers horizontally so that the film lies flat.

This 35mm print was stored vertically, without a core. Over time the film roll collapsed, causing severe warpage. Always stack film cans horizontally to avoid this problem.

When reusing old cans, make sure that they are completely free of rust, dirt, and structural damage. Any metal can showing signs of rust or breaks in its coating should be discarded.

6.7 EMERGENCY PREPAREDNESS

Most repositories have written plans for dealing with fire, floods, or other disasters. These often include lists of staff responsibilities in emergencies, supplies (including some stored off-site) for recovering collection materials, and a priority list of artifacts to evacuate. The plan for the Minnesota Historical Society, for example, covers procedures for disaster discovery, staff notification, damage assessment, insurance, recovery operations, and media inquiries, and provides appendixes with vendor lists, floor plans, and locations of disaster recovery kits. Be sure your film collection is included in your institution's disaster plan.[10]

10. To view some of the society's plan, search "Conservation: Emergency Response" at www.mnhs.org. For emergency preparedness guidelines, see Lisa Mibach, *Collections Care: What to Do When You Can't Afford to Do Anything*, Technical Leaflet 198 (Nashville: American Association for State and Local History, 1997), originally published in *History News* 52 (Summer 1997).

6.8 Long-Range Preservation Planning

By exploiting the benefits of cold storage, preservationists can develop long-range preservation plans for their film collections, providing public access through copies and scheduling film-to-film duplication over many years. Each institution must decide how to balance its preservation and access mission within the resources at its disposal. Northeast Historic Film demonstrates what is possible once cold storage becomes the anchor for institutional decision making.

In 2000, Northeast Historic Film received a three-year challenge grant from the National Endowment for the Humanities to improve conservation and expand educational programs. At the center of the effort was a new storage facility. In this structure, which opened in 2003, the moving image collection is maintained at 45°F and 25% RH. All safety film originals, masters, film copies, and video masters are kept in this environment. Access videos are shelved in the former film storage room, now the staging area, which is set at 65°F and a relative humidity between 35% and 65%. An off-the-shelf frost-free freezer houses acetate materials in advanced decay. All nitrate films have been transferred off-site.

With its storage conditions slowing film deterioration, Northeast Historic no longer has to mount emergency film-to-film duplication projects. When films are acquired, the repository makes low-cost videotapes for public service and moves the originals and new video masters to cold storage.

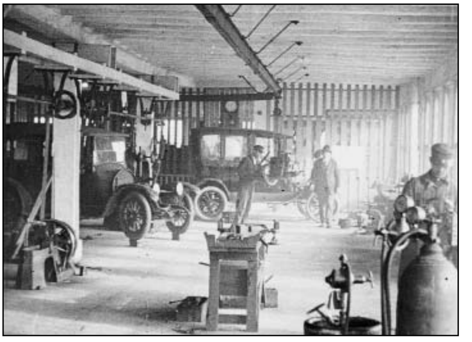
The repository has already copied its small nitrate collection onto safety film and prioritized preservation copying of its other holdings on the basis of age, condition, rarity, geographic coverage, and content. Northeast Historic can now schedule film-to-film duplication when it receives outside grants or gifts.

Table 9. Integrated Film Storage and Duplication Planning at Northeast Historic Film

Storage		
Moving Image Material	**Storage Conditions**	**Expected Life Span**
Access videos	65°F and 35%–65% RH	20 years
Originals, film and video masters, film copies	45°F and 25% RH	Extended
Acetate originals in advanced decay	Frozen	Dependent on film condition
Nitrate originals	Off-site	Dependent on film condition
Duplication		
Access videos	Made when films are accessioned and cataloged	
Film masters and prints	Scheduled, as funds become available, for items of special rarity, age, content, and condition	

Case Study: Nebraska State Historical Society

Increasing Farm Efficiency, or Delco Farm Lighting **(1918, 2,200 ft., 35mm nitrate, black and white, silent), preserved by the Nebraska State Historical Society.**



Cold and dry storage is the single most important factor in extending the useful life of film. The story of the rescue of *Increasing Farm Efficiency*, a 1918 promotional film for a Delco electric generator franchise, illustrates the causal link.

In late 1918, William B. Lowman of Silver Creek, Nebraska, spearheaded an unusual film project. A natural entrepreneur, Lowman sold kerosene-powered generators for Delco Company and rapidly expanded his business. He was so successful that Delco named him Salesman of the Year for 1918. Lowman invested the cash prize by hiring Harold Chenoweth to make a film about his franchise. The Lincoln-based filmmaker set about demonstrating how electric lighting could transform rural life, filming Lowman's own operations as well as the illuminated interiors of farms, businesses, homes, and even a church.

Increasing Farm Efficiency fell from sight for many years, although it remained the subject of family lore. In 1997, Lowman's great-grandson tracked down a nitrate print and donated it to the Nebraska State Historical Society.

Given the film's casual storage over the years, it is not surprising that the print had suffered damage, from broken sprockets to warping and shrinkage. Ten percent had deteriorated beyond salvage. As an emergency measure, the society immediately made a video copy.

In 1999, with grant support and additional funds from the Nebraska Public Power District, the society sent *Increasing Farm Efficiency* to a laboratory equipped to handle 35mm nitrate. Unfortunately, during the two intervening years the print had continued to deteriorate. Stored at 62°F in a sealed plastic bag, the film had lost an additional 5% of image content. Thus a lesson in film storage came with a high price to this unique work. The lab cleaned and repaired the remaining film. Using wet-gate printing to minimize the carryover of scratches from the source material, the lab produced a new 35mm negative and print.

Increasing Farm Efficiency has been consulted by scholars and local historians and showcased in public programs on filmmaking in the Great Plains. As one of the few surviving works of Chenoweth, the film also serves as a reminder of the many production companies that thrived in the early years of the motion picture.