analog preservation
STiL
CASING SOLUTION

The following is a small compendium of some of the texts in which North American archivists found the conviction that archival vented polypropylene film containers were superior to metal cans.

You will find as well an interesting comparison of the different type of containers done by the AMIA in 2002 and, from the OSHA, the proof that polypropylene is not hazardous for the health.

We tried to provide you with a good array of opinions that guide us in designing the STiL Design® Archival Film Container.

The STiL Design® team.

Vous trouverez ci-après un recueil de textes de base qui ont convaincu plusieurs archivistes d'Amérique du Nord de la supériorité du boîtier ventilé de polypropylène.

Vous lirez entre autres une intéressante comparaison des différents boîtiers réalisée par l'AMIA en 2002 et la preuve que le polypropylène n'est pas un produit dangereux pour la santé.

Nous avons essayé de vous fournir une variété d'opinions et d'idées qui nous ont menées au design du boîtier d'archivage pour film de STiL Design®.

L'équipe de STiL Design®

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This is Chapter 6 taken from the Film Preservation Guide of the National Film Preservation Fund (USA).

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].

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, audio-tapes, 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 distils some of the key recommendations for motion picture materials.

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[1] 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).

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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 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 is, the slower the decay.

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

Film Material	Room 68ºF (20ºC)	Cool 54ºF (12ºC)	Cold 40ºF (4ºC)	Frozen 32ºF (0ºC)
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 damages	B&W: Meets ISO recommendations Color: causes significant damage	B&W: Provides extended life Color: Meets ISO recommendations	Provides extended life
Video tape, magnetic sound track, and prints with magnetic sound tracks	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

This table summarizes how temperature affects the longevity of motion picture materials when the relative humidity remains between 30% and 50%. To evaluate how your storage conditions

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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%.

If you are unable to gather this information by computer, you can use an inexpensive thermohygrometer, which measures both temperature and relative humidity[3.] 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 artefact 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.

[3] 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

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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.

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 Cold storage vault, set at 40°F and 30% RH, with films shelved horizontally 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 Acetate films at the A-D Strip level freezer or refrigerator is discussed later).

Off-site storage

A second option is to rent storage space from a commercial vendor. A number of North American firms operate film storage facilities —some 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 non-profit or public film repositories. Some organizations have also formed consortia and pooled resources to develop group storage space.

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[4]. 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 our a hygrometer. The manual approach requires a greater investment of staff time.

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.

REMOVING AND RETURNING FILM 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. 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 warming time depends on the film mass.
A large roll of 35mm will require more time to acclimate to the new conditions than a tiny reel of

[4] 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.

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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.

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[5]. 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 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, Kodak recommends its disposal by a federally authorized hazardous waste facility.

[5] 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).

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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.

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 non-corroding 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[6].

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.

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] 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

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Extract of an article written by The Late Ed H. Zwaneveld
(from the Technological Research and Development of the National Film Board of Canada)

THE CHOICE OF FILM-FRIENDLY CONTAINERS

The choice of containers requires a clear understanding of the life expectancy objectives, consideration of the macro-environmental (storage vault) conditions, the nature of film material, and whether the container will remain inert and stable during the lifetime of the film element stored inside it**.** All enclosures used must pass the Photographic Activity Test (PAT), described in ANSI Standard IT9.2.

The tin-coated sheet iron metal raw film stock can has almost universally been used to store film elements in laboratories, vaults and archives, including nitrate-base film materials. The film manufacturers packaged the raw film stock in them; hence it was assumed that they were also suitable for storage purposes, which they are not.

When archivists monitored their film collections, they noted that the interior of such cans would often start to rust before the outside! The explanation for this phenomenon is that the out gassing of acid vapors emanating from actively degrading film caused such oxydation. Dr. Karel Brems[7] of film manufacturer Agfa-Gevaert, Mortsel, in Belgium, stated:

> *"Since the deterioration (of triacetate film) is catalyzed and auto-catalytic, one should try to prevent the reaction to reach the auto-catalytic point. This means that the released acetic acid should in no way accumulate in the film material. Therefore, we believe that the film material should not be stored in a tightly closed can or plastic bag, but in an open, well ventilated clean area. […] This means that using metal cans is a real risk factor in an archive".*

Considering that nitrate film is also subject to out gassing, the same advice also applies to nitrate film storage.

[7] Dr. Karel Brems, *Vinegar Syndrome Update-The Alternative: Polyester Film Base,* in Image Technology, March 1991, pp. 94-96.

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VENTILATION IN CANS

Another text by Ed H. Zwaneveld taken in the Archives of the AMIA-List. This one is about vented film cans.

Greetings,

At the AMIA Preservation Committee meeting during the AMIA 2000 Conference in Los Angeles, CA, in 2000, Mick Newnham of ScreenSound Australia impressed us with a thoroughly done piece of original research to determine how ventilation of film cans can be optimized.

His work has recently been published in the January 2002 SMPTE Journal, (pp.29-33) entitled: "Ventilated Film Cans-Their Effect on the Diffusion of Decomposition By-products from Motion Picture Film". It is recommended reading and as intended will provoke reflection and discussion among his peers about the meaning and applicability of his findings.

Having specified and evaluated ventilated film containers for archival storage of our substantial film collection at the National Film Board of Canada some years ago, that resulted in the STIL Design archival containers, (http://www.stilcasing.com) a few constructive comments about the findings and their meaning may be appropriate at this time.

To do the ScreenSound tests, holes were cut into various positions in the lower bottom half of the film cans tested. Tests indicated to obtain maximum flow, that two slots at opposite sides of the film pancake are most effective for maximum ventilation. Such ventilation is made possible by the free space above the film pancake, and also below it. Ridged matting was placed on the floor of the lower half of the container, which encourages airflow below the film pancake to be channelled between the slots. This enables complete air circulation around the film pancake and effective venting of vinegar syndrome out gassing products from rolls of triacetate film. Acid concentration gradients plotted show that the head or outer side of the film and the middle of the roll measured decreased free acid, while the inside or tail part of the roll remained virtually equal to that in an unvented container.

Discussion: The work proves that effective ventilation of vinegar syndrome out gassing products in the initial amount of >100 ppm is feasible in the presence of a storage environment air circulation airspeed of 0.3 m/sec (approximately 1 km/h or 0.675 mi/h), that is capable of reducing acetic acid concentration in a vented can to 4 ppm. It should be noted that this level of efficiency would probably not apply when there is no air circulation in the storage vault. It would also depend on the size of the slots or holes in the sides of the container. Also, the presence of open holes or slots in the side of film storage containers in archives, is not expected to provide adequate protection in case of sprinkler or fire extinguishing water gushing down the racks. It is also understood that the presence of free acid is unequal between the head, middle and tail of a roll of degrading film. Hence sample measurements of film shrinkage should also be made at the head, middle and tail of a roll of film to be trustworthy.

To appreciate what happens when triacetate materials degrade, let's review what we know about it. I quote from John Morgan, "Conservation of Plastics-An introduction to their history, manufacture, deterioration, identification and care", published by the Plastics Historical Society and the Conservation Unit, Museums & Galleries Commission, London, UK, 1991 (ISBN: 0 948630 14 0) pp. 23-24:

> *"Cellulose acetate plastics generally contain a relatively large proportion of liquid plasticizer which readily migrates to the surface and is easily lost. Shrinkage follows plasticizer loss and causes stress and distortion, and eventually leads to splitting. Hollow objects and containers lose plasticizer more quickly from external surfaces and are especially prone to distortion. [...] because of its susceptibility to plasticizer loss, cellulose acetate should not be stored under such well ventilated conditions as cellulose nitrate. To minimize plasticizer loss do not wrap in very absorbent materials. A loosely wrapped single tissue is recommended."*

On the other hand, we cannot permit the build-up or 'trapping' of acetic acid that outgases from degrading triacetate film either. I quote from the Image Permanence Institute "Storage Guide for Acetate Film", p. 3, under the heading "Importance of Acid Trapping by Enclosures":

> *"There is another important fact to know about vinegar syndrome besides its temperature and RH dependence: the "acid trapping" factor. The process of deterioration generates acetic acid (vinegar) inside the plastic film base.*
>
> *Under some circumstances, acidity either can leave the film by evaporating into the air, or can become absorbed into storage enclosures. In other situations it can be trapped-prevented from escaping by the storage container. If trapped, it greatly accelerates the rate of deterioration".*

We now note that 'too much ventilation' will actually increase film shrinkage, and from what we noted before, such shrinkage will be uneven between the head, center and tail of a roll of film. That means that the YCM pan separations made for protection against color dye fading when made on triacetate film, due to uneven shrinkage, may not match up anymore with the expected and required precision. Obviously, we should not make them anymore on triacetate film, but on polyester stock instead. But worse, uneven shrinkage within a single roll of film is impossible to correct when printing with an adjustable sprocket pitch on the printer, which is unlikely to be variable within a roll of film. Another observation is appropriate here, which relates to the use of zeolite molecular sieves which are known to effectively reduce the presence of humidity (and evaporated plasticizer and acetic acid) from the part of the material where it can do its job, to as low as 15%. Again, a means of encouraging uneven shrinkage, unless the film is wound once periodically and is left rather slack and not tightly packed!

At the same AMIA Preservation Committee meeting, we were shown a slide of a badly shrunken piece of degraded triacetate film. It revealed a disturbing problem for which we have no solution in the motion picture industry; it is not even a candidate for digital restoration either. It showed what happens when the film emulsion which has not shrunken as much as the triacetate film base from which plasticizer and acetic acid have evaporated, tries to hold onto the reduced piece of film base. It wrinkles up, forming ridges of increasingly unrecognizable 'creased' picture information.

The phenomenon of rapid shrinkage is also encountered with triacetate-based photographic sheet film (which is not usually as tightly 'packed' as the wraps in a roll of motion picture film), and therefore enjoys more ventilation or absorption of the evaporated plasticizer and acetic acid into the paper storage box. When such shrinkage occurs, or when the glass support is cracked and efforts are required to save the emulsion itself, very careful separation of the emulsion from the film base is attempted to save the photograph, and is then applied to a new clear film base.

About this hairy procedure I quote A.H.S. Craeybeckx, in the "Gevaert Fotohandboek (in Dutch)". First, with a small knife cut into the sides of the sheet of film negative, then leave it immersed for at least half an hour in a solution of 800 cubic cm of water, 30-40 g of sodium carbonate (dry), 50 cubic cm of Formol, 10 cubic cm of glycerine and top it off to obtain 1000 cubic cm or 1 litre.

Next take the negative out of the solution, quickly removing excess liquid and then hang it up to dry without further rinsing. When dry, place the film sheet in a 5% solution of hydrochloric acid that will do its work immediately. The gelatine layer will detach from its broken glass or shrunken triacetate film base. After the receiving substrate has been pre-treated with an adhesive layer, the emulsion is placed on it. Before or after its application, the new film needs to be washed, (without tearing it of course) to eliminate the salts used to remove it from its previous base.

I am only quoting this procedure from the photographic world and presenting it to the motion picture world to illustrate that this is no mean task, and hardly likely to ever be used, but it is the only approach we know of to find a new non-shrunken base on which a wrinkling emulsion may find a new support.

Which leads me to conclude, that we have an excellent instance of how excessive ventilation can be a new risk? We should plan to encounter the consequences of it as late as possible, while avoiding a damaging build-up of acetic acid. Whatever we do, and I paraphrase Jean-Louis Bigourdan at the Image Permanence Institute, cold and dry storage are the most effective means to reduce degradation of both acetic acid (and plasticizer) loss and color dye fading. Hopefully the

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eventually unavoidable state of the film support will take yet a very long time to arrive at your doorstep!

I hope that this will be a helpful perspective on this most interesting work.

Ed H. Zwaneveld, Director,
Technological Research and Development, National Film Board of Canada

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AMIA 2002 EVALUATION OF FILM CONTAINERS

	Archival board box	Nonvented plastic can	Nonvented metal can	Vented plastic can	Vented Metal can	Sealed can
Materials	Archival cardboard containing alkaline buffer and sometimes zeolites.	Polypropylene. Earlier products used polyethylene. Plastic may contain flame retardant. Color based on pigments.	Steel with either tinplate or anti-corrosion coating (e.g., Kodak latex-based paint).	**Polypropylene. Plastic may contain flame retardant. Color based on pigments.**	Stainless steel with replaceable filter insert.	Plastic or metal. (Molecular sieves may be added inside can). Moisture-proof materials should be used.
Design	Commonly, cardboard box with metal edges.	May be circular or square.	Molded ridges on cover and bottom.	**Various designs.**	Perforated can (lid and bottom).	Variable.

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	Archival board box	Nonvented plastic can	Nonvented metal can	Vented plastic can	Vented Metal can	Sealed can
Durability	Short term.	Long term.	Long term.	**Long term.**	Long term.	Long term.
Stackability	Not suitable for stacking more than a few 1000ft film rolls. Load on bottom box can be an issue in a stack of several boxes.	Depends on can design.	Interlocking can designs optimize stackability. Load generally is not an issue	**Depends on can design.**	Load is not an issue. Not interlocking design.	Depends on configuration
Shipping	Not suitable.	Suitable.	Suitable.	**Suitable.**	May not be suitable.	Depends on configuration.

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	Archival board box	Nonvented plastic can	Nonvented metal can	Vented plastic can	Vented Metal can	Sealed can
Fire protection	No fire protection.	Some fire protection.	Some fire protection.	**Some fire protection**	Information not available.	Depends on configuration.
Protection against water damage	Flood: No Overhead: No	Flood: No Overhead: Yes	Flood: No Overhead: Yes	**Flood: No** **Overhead: Yes**	Flood: No Overhead: No	Flood: Yes Overhead: Yes
Inertness	Archival cardboard must pass PAT.[1]	Enclosure materials must pass PAT	Enclosure materials must pass PAT	**Enclosure materials must pass PAT**	Enclosure materials must pass PAT	Enclosure materials must pass PAT
Corrosion	Corrosion is not an issue with cardboard.	Corrosion is not an issue with plastic.	Anti-corrosion coating provides suitable resistance.	**Corrosion is not an issue with plastics.**	Highly resistant to corrosion.	Depends on enclosure type.

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	Archival board box	Nonvented plastic can	Nonvented metal can	Vented plastic can	Vented Metal can	Sealed can
Control of vinegar syndrome	Porosity of cardboard material helps. Under cold conditions benefits are marginal.	Should only be used under cold conditions	Should only be used under cold conditions	**Ventilation helps. Under cold conditions benefits are marginal.**	Ventilation helps. Under cold conditions benefits would marginal.	Use of absorbents (e.g. molecular sieves) helps. Under cold conditions benefits are marginal.
Recommended uses	Suitable for short-term storage. Not recommended for long-term storage because of limited durability.	Suitable for most uses; not recommended for film collections affected by chemical decay except under cold storage conditions.	Suitable for most uses; not recommended for film collections affected by chemical decay except under cold storage conditions.	**Suitable for most uses; optimal for film collections affected by chemical decay when combined with proper storage.**	Should be suitable for most uses; should be optimal for film collections affected by chemical decay when combined with proper storage.	Not practical for large collections. May be used in the absence of RH control. Often used in conjuction with absorbents (e.g., molecular sieves) or at subfreezing temperatures.

COMPOSITION AND INFORMATION ON INGREDIENTS

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The criteria for listing components in the composition section are as follows: carcinogens are listed when present at 0.1% or greater; components which are otherwise hazardous according to the Occupational Safety & Health Administration (OSHA / USA) are listed when present at 1.0% or greater; non-hazardous components are listed at 3.0% or greater. This is not intended to be complete compositional disclosure.

Product and/or Component(s) Carcinogenic According to :

OSHA IARC NTP OTHER NONE X

Composition :

Chemical Name	**CAS Number**	**Exposure Limits**	**Range in %**
Propene, polymer with ethane	9010-79-1		> 99.0
modifiers/additives	CBI		< 1.0
Particulates not otherwise regulated (PNOR)		15 (mg/m³) TWA-OSHA (TOTAL DUST) 5 (mg/m³) TWA-OSHA (RESPIRABLE FRACTION)	
Particulates not otherwise classified (PNOC)		10 (mg/m³) TWA-ACGIH (INHALABLE PARTICULATE) 3 (mg/m³) TWA-ACGIH (RESPIRABLE PARTICULATE)	

This product is considered non-hazardous according to OSHA (1910.1200). The information contained herein is believed to be accurate. It is provided independently of any sale of the product for purpose of hazard communication as part of STiL Design. It is not intended to constitute performance information concerning the product. No express warranty, or implied warranty of merchantability or fitness for a particular purpose is made with respect to the product or the information contained here.

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VINEGAR SYNDROME DETECTION IN CTA MOTION PICTURE FILM MATERIALS

One of the most significant failure mechanisms of Cellulose Triacetate (CTA) film support is its degradation due to exposure to hydrolysis inducing storage temperature and relative humidity (RH).[1] The rate at which this degradation occurs varies with storage environment, manufacture, efficiency of laboratory processes, the coating on the film, i.e. magnetic sound coating doubles the rate of degradation as compared with film materials with a photographic emulsion. It is also influenced by the material of which the container is made, and whether it traps the acetic acid (vinegar) or allows its evacuation.

DETECTING THE VINEGAR SYNDROME[8]

It is possible to detect an active vinegar syndrome state inside a film container by briefly opening it. If a vinegar smell is present, active degradation is taking place. If the material is still stored in the tin-coated metal raw film stock can supplied by the film stock manufacturer, the interior may exhibit brown powder and may even be corroded. This indicates that active film base degradation started some time ago.

> It is recommended to use a diagnostic tool to assess the degree of degradation, referred to as Acid Detection (A-D) strips.[9] These monitoring and indicator strips, when inserted in the film storage container, may change color. If the strip remains blue (level 0), its pH is 5.0 or higher and it remains "fresh". If the color turns dark green (level 1), light green (level 2), or yellow (level 3) it is gradually more seriously degraded. The sampling procedures enclosed with the A-D strips outline the measures to be taken, ranging from cool to freezing storage temperatures to immediate duplication or copying.

Degraded film typically shrinks and may also curl. Because the magnetic sound film elements degrade faster, it will be increasingly difficult to match picture and its associated magnetic sound in terms of synchronization and length.

If triacetate film acidity evaluation is required for a collection, it is recommended to sample the film inside several containers for each year represented in the collection, to delineate the extent of the problem. It may not be possible to immediately implement the recommendations intended to slow down or halt film base degradation.

Nevertheless, it is strongly recommended to separate "degraded" film elements from "fresh" film elements. Film inside metal cans with a rusted interior, should be transferred to **archival quality and inert storage containers.**

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[8] Other forms of degradation include color dye fading, silver image fading, wear, torn or stretched perforations, generational duplicating quality loss, mold, etc.

[9] Available from Image Permanence Institute (IPI), tel. +1-716-475-5199, or fax. +1-716-475-7230.

If the air circulating and entering film storage vaults is filtered effectively to remove acetic acid vapour and other airborne pollutants, store “fresh” film as well as “degraded” film in **ventilated storage containers**. This prevents a damaging level of acetic acid vapour build-up inside them and reduces the effect of accelerated auto-catalysis. If the film storage vault is not temperature and humidity controlled and unfiltered, non-ventilated inert containers may be used with molecular sieves[10] enclosed inside. Molecular sieves absorb excessive humidity, acetic acid and other harmful contaminants and slow down degradation of the film base as well as the film color dyes.

To determine the conditions required to meet film life expectancy requirements, use the “IPI Storage Guide for Acetate Film” and consult the associated ranges of storage conditions and the approximate number of years before acetic acid degradation onset. Selection wheels are included for “fresh” film and “degraded”.

CTA FILM

When ordering duplicates to replace degraded film elements, request polyester film stock to be used, rather than cellulose triacetate (CTA) materials.

In order to periodically monitor the level of degradation in terms of the vinegar syndrome, color dye fading, damage, etc., it is highly recommended to record the evaluation results in a database related to each film element. In time, it will serve to indicate the speed of degradation and will enable verification of the assumptions made about ways to halt degradation, remaining life, etc.

[10] See: http:www.fpcfilm.com/US/en/motion/FPC/fpc/mole.html and http://www.kodak.com/country/US/en/motion/support/technical/vinegar.shtml

STORAGE CONTAINERS FOR NITRATE FILMS

NITRATE FILM DEGRADATION

Introduced at the dawning of cinematography in August 1889 by Eastman Kodak, nitrate film retired from cameras and laboratories about 1951-52. It is an outstanding black and white film, but unfortunately is also a relatively unstable material that is considered a fire hazard.[11] When stored in large quantities of about 5,000 feet or more and in non-approved storage cabinets without proper ventilation, it is a fire hazard.[12] As it degrades, it emits nitric oxide, nitrogen dioxide, and other gases that yellow the filmbase, soften the gelatin, and oxidize the silver image. The odor is slightly reminiscent of chlorine bleach. These gases are also deep lung irritants.

Five stages of nitrate film degradation have been identified.[13]

Level 1: The negative begins to turn yellow or amber and mirrors, indicating that sulfiding has begun. The image is also fading. To confirm, see whether the film is brittle and breaks easily when bent in half, especially with the emulsion side out. At this stage, the gelatin is probably soft enough to dissolve readily if the film is wetted[14];

Level 2: The film becomes sticky, layers stick together and the film becomes brittle and emits a strong noxious odor (nitric acid);

Level 3: The film contains gas bubbles and gives off a noxious odour;

Level 4: The film is soft and can weld to adjacent layers and is often covered with a viscous froth;

Level 5: The film degenerates into a brownish acrid powder.

It has been established that *nitrate*, and its safety film replacement *cellulose triacetate film base*[15] materials, are both subject to increased rates of degradation in vapor-tight sealed containers as compared with ventilated open enclosures. Low film winding tension allows acid

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[11] A.H. Nuckholls and A.F. Marson, *Some Hazardous Properties of Motion Picture Film,* SMPTE Journal, December 1936.

[12] Kodak: *Storage and Handling of Processed Nitrate Film,* http://www/kodak.com/US/en/motion/support/technical/storage3.shtml This site also explains how to identify nitrate film and how to dispose of it.

[13] National Museum of Photography, Film & Television, *Nitrate Film,* Information sheet 5.3 NMPFT 2000, http://www.nmpft.org.uk

[14] Kodak: *Storage and Handling of Processed Nitrate Film*: http://www.kodak.com/US/en/motion/support/technical/storage3.shtml

[15] Jean-Louis Bigourdan and James M. Reilly, *Environment and Enclosures in Film Preservation,* Image Permanence Institute, 1997, p. 30

vapor diffusion from the film surfaces and, as a result, can enhance the benefit of open enclosures on film base stability.[16] The degradation processes of both media produce out gassing, the build-up of which accelerates degradation. In fact, storing nitrate film in vapor-tight containers is outright dangerous! As Kodak[17] warns:

> *"While it deteriorates, nitrate base film makes a kind of pressure cooker of the film can in which it rests, especially when it is taped closed. If the gases can't escape, heat builds and spontaneous combustion may not be far behind.[18] It can ignite spontaneously at temperatures as low as 49ºC (120ºF). Therefore, nitrate film must never be closed in. Escaping toxic gases (powerful oxidizing agents) can attack nearby triacetate and polyester base films, so store nitrate films in their own special place and not in a place too heavily concentrated."*

Nitrate and triacetate films should never be stored together.[19] Unstable or decomposing nitrate film produces nitrogen dioxide gas. It has a three-fold effect on triacetate film[20]. During the first stage it discolours and starts to fade the image, followed by attack and degradation of the emulsion gelatine, finally the triacetate film base will decompose.

RECOGNIZING NITRATE FILM MATERIAL

To be sure that all nitrate film is identified as such, even when spliced into a reel of otherwise triacetate-based film, it is necessary to have simple means to identify it.

The simplest of the non-destructive methods to quickly observe whether a roll or parts of it consist of nitrate film is to (1) view the edge of the pancake roll with an *ultraviolet lamp*. Nitrate film base looks black and triacetate film appears bluish purple. Or (2) check the *visible frame line mark on processed film between every set of four perforations*. If it is oriented in a linear direction between the perforations it is safety film, and when it points width-wise across, it will be nitrate film. A *float test* (3) requires some trichloroethylene and a flask or glass tube. It is a toxic and carcinogenic solvent, which dictates doing the test in a well-ventilated area while wearing rubber gloves. Insert the sample film in the solution; shake the container so it will be immersed completely. When a piece of nitrate film, which is the densest, is immersed in this solvent, it will sink. Triacetate film will rise to the top. Polyester film will float about half way down in the tube. A destructive *burn test* (4) is also the most dangerous one, it burns

[16] ibid. p. 30
[17] Kodak: *Storage and Handling of Processed Nitrate Film,* http://www/kodak.com/US/en/motion/support/technical/storage3.shtml
[18] J.W. Cummings, A.C. Hutton, H. Silfin, *Spontaneous Ignition of Decomposing Cellulose Nitrate Film,* SMPTE Journal, **54** March 1950, pp. 268-274.
[19] J.F. Carroll and J.M. Calhoun, *Effect of Nitrogen Oxide Gases on processed Acetate Film,* SMPTE Journal **64,** September 1955, pp. 501-507.
[20] Storage of Motion Picture Film, *Examination and Evaluation of Existing Material*: http://www.wrslabs.com/filmstorage.html

quickly and with a characteristic yellow flame. Nitrate film cannot be extinguished, so keep a large container of water nearby to immerse the burning film if needed. Triacetate and polyester film are much less flammable, hence they burn slowly. To do the test, snip off a piece of the clear film leader, hold it with metal thongs and ignite it from the top. Only nitrate film will burn in a downward direction.

CREATING A FILM-FRIENDLY STORAGE ENVIRONMENT

The prevention of decay in the first place is the highest and most productive priority, although for nitrate film this is now at least 50 years overdue. Thus establishing the most beneficial setting for the film elements can be created by (1) reduced storage temperature, (2) reduced humidity and control of humidity variation levels and (3) acid vapour concentration reduction and (4) storage in inert containers.[21] Douglas Nishimura at the Image Permanence Institute indicated that the aging of nitrate film tested showed to be very humidity dependent.[22]Keeping the film at a drier 20% RH would improve its life expectancy by possibly as much as 10 times.

There are several approaches to achieve a film-friendly storage environment, i.e. a fully climate-controlled macro-environment or a micro-environment where the humidity and acid vapour concentration in storage are controlled inside the container. The micro-environment approach seeks to control humidity and out gassing when it is not possible to avoid higher than required humidity in the storage environment. This approach is based on the use of moisture and acid adsorbents for fresh or new film, such as desiccants, acid scavengers and moisture preconditioning to lower relative humidity either before or during storage. It is intended to delay the onset of hydrolysis-related degradation. This method is ineffective when used for film that is already actively degrading,[23] although it has been shown to reduce the rate of color dye fading. It is assumed of course, that the desiccant will be replaced before it becomes saturated, as it would eventually become ineffective.

The micro-environmental approach is not appropriate for nitrate film storage. The necessity of sealing the film container is unacceptable and dangerous for nitrate film and the storage vault, risking self-ignition of the film.

THE CHOICE OF FILM-FRIENDLY CONTAINERS

The choice of containers therefore requires a clear understanding of the life expectancy objectives, consideration of the macro-environmental setting, the nature of nitrate-based film material, and whether the container will remain inert and stable during the lifetime of the film element stored inside it. All enclosures used must pass the Photographic Activity Test (PAT), described in ANSI Standard IT9.2.

[21] ibid, p.31
[22] Douglas Nishimura correspondence, August 10, 1990: http://www.ph.utexas.edu/~erickson/nitrate.html
[23] ibid, p.50

The tin-coated sheet iron metal raw film stock can has almost universally been used to store film elements in laboratories, vaults and archives. The raw film stock was packaged in them, hence it was assumed that they were also suitable for storage purposes.

When archivists monitored their film collections, they noted that the interior of such cans would often start to rust before the outside! The explanation for this phenomenon is that the out gassing of acid vapours emanating from actively degrading triacetate film caused such oxidation. This oxidation process can easily be demonstrated by placing a little vinegar inside such a film can, and inspecting the inside after a few days of storage at room temperature!

That is not all, Norman S. Allen reported in 1992[24] that the presence of metal ions has an adverse effect:…the results show that the degradation rate for film in contact with metal containers, as measured by viscosity retention, is markedly increased in comparison with that of film aged in contact with glass containers…The results shown affirm the implication that iron is a significant contributor to the degradation reaction… It is likely therefore, that the iron is acting as a redox reagent, instigating the breakdown of active hydro peroxides."

Dr. Karel Brems[25] of film manufacturer Agfa-Gevaert, Mortsel, in Belgium, stated:

> *"Since the deterioration (of triacetate film) is catalyzed and auto-catalytic, one should try to prevent the reaction to reach the auto-catalytic point. This means that the released acetic acid should in no way accumulate in the film material. Therefore, we believe that the film material should not be stored in a tightly closed can or plastic bag, but in an open, well ventilated clean area […] This means that using metal cans is a real risk factor in an archive."*

The above conclusions were reached in connection with storage containers for currently prevalent triacetate film materials. With nitrate materials it is absolutely essential to have ventilated containers. The Library of Congress[26] states:

> *"Cans of nitrate film that has remained closed for some time should be opened in unconfined, well-ventilated spaces. If gases given off by decomposing nitrate-based film are trapped in a confined space—such as in a sealed can—they can ignite at temperatures above 100ºF (37.8ºC).*

[24] Norman S. Allen, Michele Edge, and Terence S. Jewitt, *Degradation and Stabilization of Cellulose Triacetate Base Motion Picture Film,* in Journal of Imaging Science and Technology, Vol. 36, Number 1, January/February 1992, pp. 4-12.
[25] Dr. Karel Brems, *Vinegar Syndrome Update-The Alternative: Polyester Film Base,* in Image Technology, March 1991, pp. 94-96.
[26] Library of Congress-Preservation- *Care, Handling and Storage of Motion Picture Film*, :http://www/loc.gov/preserv/care/film.html

Nitrate film is highly flammable, ignites easily, and cannot be extinguished after burning has begun."

High Density Polypropylene ventilated film containers are now available for both nitrate and triacetate film storage.

It has been observed that non-photo-stabilized polypropylene (PP) in outdoor uses is limited by its embrittlement caused by photo-oxidation. The impact of UV light and of heat is shown by an increase in the Thickness of the Oxidized Layer (TOL) in non-photo-stabilized PP. The increase of this oxidation has been shown to be independent of the light intensity and to be caused primarily by heat.[27] It is possible to order High Density Ventilated Polypropylene film containers that contain a photo-stabilizer or alternatively to use fluorescent light tube filter sleeves to filter out UV radiation.

All nitrate base film in either a working or archival status must be stored in an approved vented cabinet or vault. Standards exist for the construction of such approved storage areas, including archival film vaults, film cabinets, projection rooms and film exchanges. They have been developed by the US National Board of Fire Underwriters and National Fire Protection Association. It is available under the title NFPA 40: Standard for the storage and Handling of Cellulose Nitrate Motion Picture Film, 2001 Edition, 18 pp. US $ 21.00, and is obtainable by e-mail: nfpa@normas.com, or by phone: +1-801 374-6214, by fax: +1-801-374-0634.

[27] S. Girois, P. Delprat, L. Audoin and J. Verdu, *Oxidation thickness profiles during photooxidation of non-photostabilized polypropylene,* in Polymer Degradation and Stability, **56**, (1997), pp. 169-177.

Compendium of texts

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