Cold Storage of Cultural Artifacts

v15a
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tjvitale@ix.netcom.com

General Discussion on the Need for Cold Storage

Cold storage will prolong the life of all materials. It is largely used with photographic prints, film and videotape to decrease the rate of

- **Dye fading or dye loss (color fading in dark storage)**
- **Acetate film base deterioration (Vinegar Syndrome)**
- **Nitrate base deterioration**
- **Deterioration of Resin Coating on prints (20 years to cracking, introduced approx. 1970)**
- **Yellowing of fiber based papers (most stable print base, but will yellow in 200-500 years)**
- **Inkjet dyes and pigments (colorants) on all paper and plastic media (base)**
- **Hydrolysis of binder (Sticky Shed Syndrome) in the magnetic layer of videotape**

Cold storage will not harm materials as long as the cooling and warming is done in a controlled manner, with the moisture content of the components held stable. Moisture content is an intrinsic property that is influenced by the humidity in the surrounding air, and secondarily, by temperature. In a sealed container moisture content will not change.

Paper, film-based materials and videotape can have a noticeable improvement of life when in cold storage, but the temperature of the storeroom can limit access and generally curtails browsing the collection. Cold storage will prolong the life of already partially degraded materials; it will extend the usable lifetime. Don't forget to account for the current state of the artifacts when estimating possible extended lifetimes.

Humidity-controlled vaults are generally found desirable for B&W and color print collections (including prints made on inkjet printers from digital files); where direct access is a the primary use criteria.

The more economical cold storage system is Passive Cold Storage. Passive vaults (sealed-package in a commercial freezer) are generally found to be the desirable solution for film collections.

Table 1: Comparison of cold storage vault types.

Type	Cost to Build	Cost to Run	Degree of Preservation	Degree of Accessibility
Active - Humidity Controlled Vault	**Expensive**	**Expensive**	**Not as cold**	**High**
Passive - Sealed-pkg in Freezer	**4-20 times less**	**½ to 4x less**	**Highest Possible**	**2-8 Hr Warm-up**

Frozen storage in sealed packages or cabinets, within commercial or upright freezers, is safer and far more economical, but is not as accessible or user friendly. However, there two classes of cultural materials that often do not need direct access because they are not immediately readable: film and videotape. Only experienced workers can get useful visual information from a negative, especially color negative with their orange reversal mask, and a machine must be used to playback a videotape.

Color slides are human readable, but their size requires a lightbox and loupe. This makes slides less accessible than prints, which are generally viewed at arms length.

Prints and large format transparencies are immediate human readable. It is common for one to walk into a vault, look for a print thorough drawers, boxes or cabinets and make a selection for study, examination, loan or exhibition. This is the virtue of the complex and expensive humidity-controlled storage vaults, with a higher temperature anteroom (facilitating an unsealed warm-up period).

If a collection is cataloged and there is an image-base for the materials, direct access is not necessarily required for human readable media. The user could easily wait the warm-up period, and then access the materials in the afternoon or the next morning.

Basic Chemistry of Cold Storage for Organic Materials – Generic Cultural Artifact
Organic materials are those that contain carbon in a chain. In museums, archives and libraries this includes paper, polymers in plastic films and adhesives (videotape), gelatin and related materials such as parchment, animal feathers and skins. As a group they have a generic "organic" behavior, see table 1 below. When a specific material is studied, such as cellulose acetate by IPI, then more precise information is available.

IPI has researched and produced publications that have specific storage predictions based on cold storage of (1) acetate film, **IPI Storage Guide for Acetate Film**, James Reilly, 1993, Rev. 1996 and (2) color film, **Storage Guide for Color Photographic Materials**, James Reilly, 1998.

An IPI report on magnetic tape preservation can be found online in their final report too the NEH: **The Preservation of Magnetic Tape Collections: A Perspective**, 2006, by Jean-Louis Bigourdan, James M. Reilly, Karen Santoro, Gene Salesin <http://www.imagepermanenceinstitute.org/shtml_sub/NEHTapeFinalReport.pdf>. A 1995 report on videotape by John Van Bogart: **Magnetic Tape Storage and Handling, A Guide for Libraries and Archives,** can be found at <http://www.clir.org/PUBS/reports/pub54/2what_wrong.html>.

It has been assumed that nitrate film was a lost cause, thus a similar IPI Publication has not been done on nitrate based film. However, it was recently announced by IPI (3/07 at AIC-EMG Winter Meeting at RIT, Rochester, NY) after some prodding that the actual life of cellulose nitrate film ranges from 50 to 500 years. The following generic data is a respectable equivalent, when assessing the effects of cold storage on nitrate film.

Work done by IPI (RIT) and Mark McCormick-Goodhart (Smithsonian) on the cold storage of generic organic materials, suggests that the following improvements in life will result from storage at the following conditions:

Table 1: Effects of Cold Storage on Generic Organic Materials

85°F at 80% yields	**1/7-times improvement of lifetime**
85°F at 60% yields	**¼-times improvement of lifetime**
75°F at 60% yields	**½-times improvement of lifetime**
70°F at 50% yields	**1 times improvement of lifetime**
60°F at 50% yields	**2 times improvement of lifetime**
60°F at 40% yields	**4 times improvement of lifetime**
40°F at 40% yields	**8 times improvement of lifetime**
40°F at 30% yields	**18 times improvement of lifetime**
-4°F at 40% yields	**380 times improvement of lifetime**
-4°F at 25% yields	**690 times improvement of lifetime**
-15°F at 40% yields	**10000 times improvement of lifetime**
-15°F at 25% yields	**12500 times improvement of lifetime**
-20°F at 30% yields	**13000 times improvement of lifetime**
-25°F at 40% yields	**13500 times improvement of lifetime**
-25°F at 30% yields	**14000 times improvement of lifetime**

Note that both temperature and humidity have an influence on longevity; both change in the table above. Temperature obviously influences the energy level, the higher the energy the faster process will proceed; higher temperatures always increase the rate of deterioration. Humidity in air influences the moisture content of materials, increasing or decreasing the amount of water available for reaction. Water will soften and swell, and also react with the various polymers in film and prints. Chemical reaction with water can only decrease system entropy (degree of order), thus more water in a system increases the overall state of deterioration.

Videotape

The carrier in videotape is generally polyester plastic, but paper and metal were early prototypes (1928: paper audio tape, 1952: BBC's Vera used 2" metal video tape; and in 1954: RCA was the first to use a plastic base successfully). Thus, videotape differs from film in that the base is stable, while the binder of the magnetic layer creates the problem. The polyurethane binder, used for the magnetic pigment in the magnetic layer, which is coated on the plastic base, suffers from hydrolysis chain scission. It is sensitive to water content and humidity. Lower than normal humidity is considered desirable and cool storage is recommended.

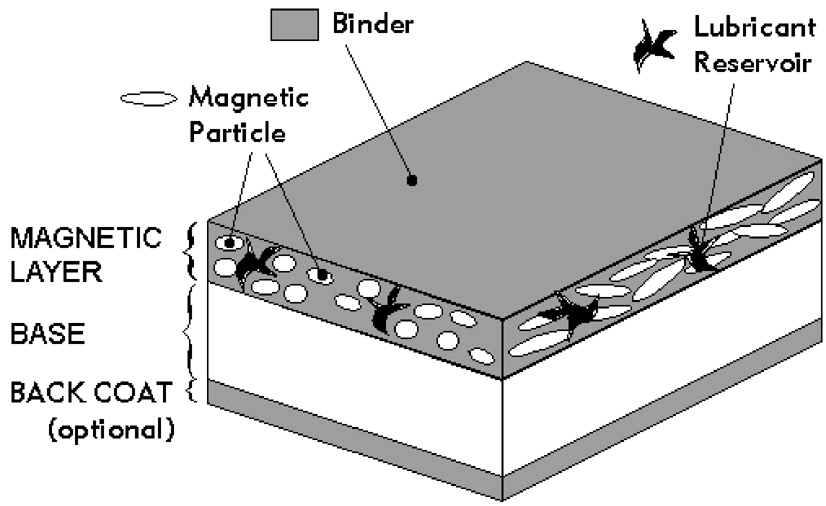

Figure 1: Image taken from *Magnetic Tape Storage and Handling, A Guide for Libraries and Archives* **(1995) John Van Bogart, found at** <http://www.clir.org/PUBS/reports/pub54/2what_wrong.html>

In approximately 1972-5, some magnetic tape manufacturers (possibly only one, but distributed to others) included a compound that forms tiny white crystals when taken below freezing; thus frozen storage is not recommended. There have been no reports that the white crystals cause harm, but with the current state of understanding frozen storage is not recommended.

There is evidence that frozen storage in a vault with unregulated humidity pulls water from videotape over time, as does freeze-drying. This would suggest damaged video tape could be rejuvenated by frozen storage in an unregulated freezer; a good topic for research.

Quoted from the IPI Report (2006) referenced above **The Preservation of Magnetic Tape Collections;** p.12 in PDF:

> "Today the preservation strategy for magnetic tape collections consists of just a few possible actions, none of which actually addresses the challenge of preserving a large quantity of material that is likely to become obsolete over time. Proper storage at a cool temperature and low RH improves binder stability. ISO provides temperature and RH guidelines for long-term storage of magnetic tape." Footnote: ISO 18923: 2000, Imaging Materials—Polyester-base magnetic tape—Storage practices, (Geneva: International Organization for Standardization, 2000).

The other issue with videotape is that it is not human readable. Videotape it requires an electronic device for playback. After about 1998-2000, DVDs took over the commercial movie market and video cassette recorders (VCR) have been on the decline. During the 1980s the sales of new professional ¾" U-Matic video tape recorders (VTR) were discontinued. By 2000 most professional VHS, S-VHS and BetacamSP video tape recorders (VTR) were discontinued. In about 30 years VTR and VCR devices will be very rare. The last source of professionally serviced historic video equipment went out of business in early 2008 (The Broadcast Store). Prolonged storage of videotape at frozen conditions may preserve the videotape for 500 to 5000 years, but devices to play videotape back may be so rare that their use may be difficult to impossible. Migration to new digital video formats must be done over the next 30 years, while VTR and playback units are still available and serviceable.

Storage at 40-50°F and 25-40%RH is the common recommendation. The use of sealed polyethylene bags in a refrigerator set to 40-45°F would be an excellent solution. It would be desirable to lower the relative humidity (moisture content) of the videotapes to 25-40% in a sealed cabinet, using a good dehumidifier, before sealing in bags. Follow the bagging recommendations at the end of this essay.

Nitrate Base Film

There have not been the in depth reports on the deterioration and cold storage of nitrate base film. Therefore, the data above on generic organic materials is used to describe their performance in cold storage.

Table 2: Effects of Cold Storage on Nitrate Base Film

70°F at 50% yields	**1 time improvement of lifetime**
70°F at 30% yields	**1.7 times improvement of lifetime**
40°F at 30% yields	**18 times improvement of lifetime**
-4°F at 30% yields	**580 times improvement of lifetime**
-15°F at 40% yields	**11650 times improvement of lifetime**
-25°F at 40% yields	**13500 times improvement of lifetime**

It was assumed until recently that nitrate base films would have a life of 20 to 60-80 years. IPI (3/07 EMG Winter Meeting) recently announced that the life of cellulose nitrate film will range from 50 to 500 years, rather than their previous series of informal predictions that nitrate film would have a 20-60 year lifetime. This earlier prediction had prompted many cultural professional to identify and destroy nitrate film. In addition, nitrate sheet film in paper envelops is not explosive, and does not give off explosive or flammable vapors. The vapor, at its worst, is dilute nitric acid, mixed with degrading gelatin (animal skin, sinew and bones).

It has been noted by numerous workers, in survey after survey, that much of the nitrate film found (made 1889 and 1951), which is now 57 to 117 years old, is largely still in L2 to L3 condition, showing only yellowing and silvering-out (image silver migrated to the surface).

Experience has shown that the average life for an "early-failure" nitrate film species was about 45-60 years. This cohort has been found to be 10-15% of collections held in storage. Significant portions (5-10%) of nitrate collections remaining on the west coast, after early failure specimens have been found and isolated, are now degraded to the L4-L5 state (brown, distorted and sticky) within 60-80 years of their manufacture. Some of this film is now unusable or has been prematurely destroyed. Most extant nitrate film, about 80% of most collections, is now about 80-115 years old. Most of this film is still in the L2 state, showing only yellowed and minor silvering-out, still quite usable.

That portion of the whole universe of nitrate film produced (production 1889 to 1948-52) that has failed early, is about 10-40 % of medium-sized collections. That is, the 10-40% of the nitrate film universe has already reached its final stages of deterioration, L4, L5 & L6. Most of these "blocks of stuck-together negatives" have been set aside as unusable, culled by non-professionals or destroyed by Fire Marshals.

Acetate Base Film

The progression of the acetate deterioration has two stages (a) initiation and (b) autocatalytic. The following graph is from James Reilly, **IPI Storage Guide for Acetate Film**, 1993, p13.

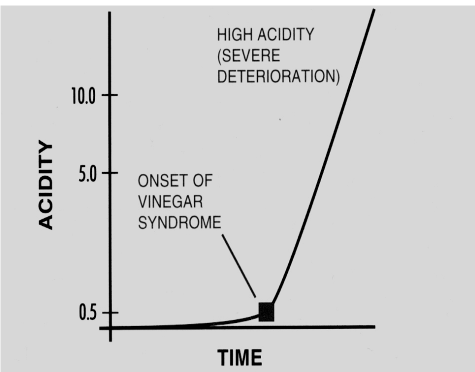

Fig. 17 Time-versus-acidity curve for acetate film. The autocatalytic part of the curve occurs at about 0.5 free acidity, the point chosen as the basis for predictions of the onset of vinegar syndrome in the *Guide*.

Figure 2: Two-stage deterioration of acetate base, taken from Reilly, "IPI Storage Guide for Acetate Film" (1993) p13.

The **initiation stage** takes about 30-40 years, at a normal rate of progression. Using the IPI, A-D Strips, the rating is from 0.0 A-D (blue) to 1.5 A-D (green). The "Free Acid" content is from 0.05 (new) to 0.5 (A-D 1.5) in the initiation stage.

When the Free Acid content is high enough, the (free) acid in the film further catalyzes deterioration without being consumed, and thus, remains available to do further damage. This stage is referred to as the **autocatalytic phase** and is far faster than the earlier phase. IPI, A-D Strips, can be used to evaluate the condition based on the free in the air surrounding the film. The A-D Strip value for autocatalytic phase runs from A-D 1.5 (medium green) to 3.0 (yellow), the highest the strips can measure. The amount of **free acid** in the film during the relatively short autocatalytic phase runs from 0.5 to 10, and sometimes even higher. The yellow color of the IPI A-D Strips reaches it maximum at a free acid content of 3.0. More acid can be generated beyond Level 3, but the state is L5-L6 or unusable. The autocatalytic stage often progresses in a very short period, 5-15 years depending on storage conditions and inherent vice in the film. There have been reports that the final phase can proceed very quickly, days, week or months, but this has not been confirmed in documented reports.

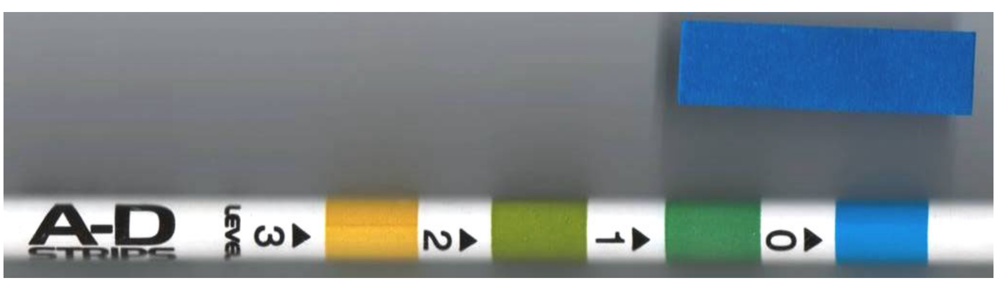

Figure 3: Image of the A-D Strip, upper right, and the tools used to judge color after exposure to the acetic aid in the head space around the artifacts made with cellulose acetate.

In sub-zero cold storage (-15°F at 30-40% RH) that short period (5-15 year) can be increased approximately 2000 times longer, up to 30,000 years. A 2000-times improvement may seem an overly large increase, until one calculates that (1) the "current" state of degradation of the material now (1.5 A-D value or 0.5 Free Acidity) and (2) the decrease in extended lifetime caused by "time out of storage" (it must be assumed that there will be some use of items in storage); see the TOS section below.

Acetate-base film will become almost unprintable in 45-100 years. Even though the long-lived silver-gelatin emulsion will last 200+ years, the acetate base can cause premature failure for some cohorts in 45 years.

It has been found, however, in surveys of several west coast collections, that only a small portion of the acetate-based materials actually follows the IPI predictions of failure in 45-60 years. The percentage of collections actually showing the "predicted" behavior is 10-20%. Most of these collections have about 80% of the acetate-based collections showing L2-L3 behavior. If the artifacts are held at cool or cold conditions, their lifetime will improve substantially.

Table 3: Effects of Cold Storage on Acetate Base Film

Lifetime for New Film, Years	Storage Conditions
45	70°F at 50%RH
175	55°F at 40%RH
1900	30°F at 30%RH (using a refrigerator)
1600	30°F at 30%RH + 5 days-out-of-storage/year
31,500	0°F at 30%RH (using upright freezer)
1900	0°F at 30%RH + 5 days-out-of-storage/year
110,000	-15°F at 30%RH (using commercial freezer)
1900	-15°F at 30%RH + 5 days-out-of-storage/year

Color Film and Prints-- Based on Color Dyes

Color photographic materials always use color dyes, be it on acetate film base, or as a positive image, on paper (fiber) or resin coated (RC), supports. It is the dyes that show the chemistry that is the subject of the Color section.

Using data from Kodak and other manufactures supplied to Wilhelm (1993) the following data, Table 4, has been generated; actual behavior will have many variables. The most significant variable would be storage, until rehoused in a cultural institution.

For the early to middle era slide films (1938-88) Kodachrome slide film has the best life in dark storage -- about 50-66 years, before significant color shift (fading of one dye). For modern slide films (1980-1995) that are to be projected, Fujichrome Velvia film has the longest life -- 5.3 hours. Fujichrome Velvia has one of the shortest lifetimes in dark storage, about 15-20 years, in a class that can have 200+ lifetimes.

Ektachrome slide film (the pre-1988 formulation, E3 & E4), the type held in most collections, has a very poor life of 14 - 46 years. Modern Ektachrome slide film (1988 to present, E5 & E6) has a life of 105-220 years. Moreover, most of these films are 20-40 years old so they have lost much of their usable life. Many show some color shift (minor to noticeable), the loss of blue and yellow dye intensity leading to a magenta cast.

Table 4: Estimated Lifetime of Color Film, Acetate Base, either Transparency or Negative

Years in Dark Storage, for 20% Dye loss*	Color Film Type		
16	Kodak	Royal Gold 100 RA Negative	
38	Kodak	VPS Vericolor Negative	
12	Kodak	6011	Vericolor Internegative
14	Kodak	5035	CII Kodacolor Negative
16	Kodak	Royal Gold 200 RB Negative	
12	Kodak	4112	Vericolor Internegative
35	Kodak	5093	Kodacolor CL 200 VR 200 Negative
38	Kodak	Gold 400 Negative	
20	Kodak	Royal Gold 25 RZ Negative	
20	Fuji	HR 1600 (1984) Negative	
15	Agfa	XR 1000 Negative	

220	**Kodak**	**5025**	**Ektachrome Transparency (64X, EPX)**
220	**Kodak**	**5075**	**Ektachrome Transparency (400X, EPL)**
40	**Kodak**	**6121**	**Ektachrome Transparency Duplicating**
105	**Kodak**	**6036**	**Ektachrome Transparency (200, EPD)**
35	**Kodak**	**5071**	**Ektachrome Duplicating**
105	**Kodak**	**5056**	**Ektachrome Elite 200 post 1988**
105	**Kodak**	**5076**	**Ektachrome 200 ED (daylight)**
66	**Kodak**	**Kodachrome 1938-1988**	
20	**Kodak**	**Eastman Color Reversal Movie (estimate)**	

Color print materials have significantly less life than B&W materials. Fiber based B&W are said to have a life of 3-500 years. On resin coated (RC) base they have a life of 20 years because the resin coating cracks due to the inclusion of titanium dioxide that acts as a radical for UV light, prematurely degrading the polymer coating. Color based materials cannot do better than B&W, thus color RC prints only have a 20 year lifetime. The best chromogenic paper, Fuji Crystal Archive has a predicted life of 45-60 years on display and several decades in the drawer.

Table 5: Estimated Lifetime of Color Print Materials, on Fiber or RC Base

Years in Dark Storage*	Color Print Material Type
50	Fiber based Chromogenic prints, often Kodak or Agfa brand
20	Resin coated Chromogenic prints, usually Kodak brand
150	Fuji Crystal Archive print (45-60 years on display)
400-800	Kodak Dye Transfer (30-50 years on display)
100	Fujichrome, 1986-92, polyester base
500+	Cibachrome, 1980-91, polyester base
500+	Ilfochrome Classic, 1991-Pr, polyester base
20?	Polaroid (Polacolor, 2 & ER: 1963, 75, 80-Pr and SX-70: 1972, 75-Pr)
0.5- 200	Digital prints 1990-Pr (6 mos. to 3 years with some notable exceptions)
100-200	Archival Digital prints 1998-2003 (40-100 years on display)
150-250**	Archival Digital prints 2004-Pr (60-250 years on display)
3-5	Color photocopies (actually, longevity unknown)

* Lifetime when new; most artifacts will already be 20 to 45 years old; end point not defined, probably 20-30% loss.

** When dark storage research has been completed for the 2004-2008 era pigment-based inks, the lifetime will increase. Yellowing of the paper base will always be the weakest link. In a 2007 study by Robin Myers <http://www.rmimaging.com/information/neutral_references.html>, UV-brighteners were found in most premium Epson papers and many other coated papers, when they fade the paper will look more yellow because the brighteners fluoresce blue.

Predicting Extended Life of Color Film in Cold Storage

Using the Reilly (1998) color dye fading data, which was calculated base on a 30% loss of the least stable dye, IPI predicts an average life of 40-45 years for early-1990 color materials. Based on the types of color films commonly held at cultural institutions (see above and below), and assuming that the average age of creation was 1987 (about 20 years ago), the lifetime of the average color film is about 25 years.

Table 6: Effects of Cold Storage on Color Dyes

Years of Life	Storage Conditions
25	70°F at 50%RH
75	55°F at 40%RH
70	55°F at 40%RH with 5 days-out-of-storage a year
170	45°F at 40%RH
125	45°F at 40%RH with 5 days-out-of-storage a year
1300	30°F at 30%RH
375	30°F at 30%RH with 5 days-out-of-storage a year
30,000	0°F at 30%RH
490	0°F at 30%RH with 5 days-out-of-storage a year
160,000	-15°F at 30%RH
550	-15°F at 30%RH with 5 days-out-of-storage a year

Taking account of time out of storage (TOS), the optimistic "lifetime" numbers drop dramatically. If we assume 5 days out of cold storage every year, storage at -15°F at 30%RH becomes about 550 years. Five days out of storage is the time it takes to have a duplicate negative or print made locally, or, to acquire a good scan. Two months is approximately the time it takes to send a group of negatives away for duplication or scanning; this is 5 days TOS over twelve years, assuming a 2-300 year lifetime.

Color Film Fading -- Predicting Lifetimes

There are few natural aging of film studies (Anderson & Ellison, 1992: 12 years of natural aging) that cover 40 years of data for the dark storage of film. Predictions can only be calculated from accelerated aging studies at elevated temperature (Kodak, 1988; Wilhelm 1993 and Reilly, 1998).

The average color film is expected to fade, in museum storage conditions, in about 40-45 years. The films with the longest relative stability are the Kodachrome 25, 64 & 200 (K-14) transparency films; later Kodachrome II (C-41) has less stability. Kodak Kodachrome and Ektachrome slide films manufactured after 1988 are predicted by Kodak to last 185-220 years in cold storage. Projection of the slide will lower it fading rate dramatically, years to hours.

According to Reilly (1998), Kodachrome (1938-Pr) film will fade to 30% single dye loss in 40-50 years. According to Kodak data (1988), a density loss of 10% will occur in 50 years, and to 30% loss of one dye, in 100 years. A 10% loss is acceptable fading, but 30% of a single dye loss is very bad. Thus, it should be assume that post-1938 Kodachrome has a useful life of 50-66 years. Based on this prediction other color films can have their behavior predicted with a fair amount of accuracy.

Table 7: Estimated Lifetime of Color Transparency Film on Acetate Base

Type	Wilhelm 20% Loss	Kodak 20% Loss	Predicted Lifetime at Museum Conditions
Ilfochrome Micrographic M & P	2555 days		290 years*
Kodachrome (post-1938, K-14)	580 days	30-115 years	66 years
Kodachrome (K-12)	580 days	30-115 years	66 years
Average transparency film rating from Reilly (1998)			40 years
Ektachrome (6121 dup: E6)	225 days	25-45 years	35 years
Ektachrome (160T E6)	225 days	25-45 years	35 years
Ektachrome (5071 dup E6)	225 days	25-45 years	35 years
Ektachrome (5017/6117 & 5018/6118)	225 days	25-45 years	35 years
Ektachrome (5036 E6)	225 days	25-45 years	35 years
Fujichrome (general)	185 days		21 years
Fuji Velvia	135 days		15 years
PolaChrome Instant	90 days		10 years
Kodachrome II (C-41)		14 years	heavily faded
Ektachrome (E1-3)		14 years	heavily faded
Ektachrome (5038 E4)		14 years	heavily faded

* Anderson & Ellison, **Natural Aging of Photographs**, JAIC 31:2, 213-223, 1992
Kodak, **Image-Stability Data: Kodak Kodachrome Films,** Kodak Publication E-105, 1988
Reilly, **Storage Guide for Color Photographic Materials**, 1998, IPI
Wilhelm & Brower, **The Permanence and Care of Color Photographs**, 1993, Preservation Publishing Co

Wilhelm (1993) and Kodak (1988) predict that Ektachrome class of films resists fading about 2-3 times less than the Kodachrome class of slide films. Kodachrome from the 1935-40 era have very poor fading properties. Kodachrome from the 1938 to 1961 era have much-improved fading properties over the first release Kodachrome films, on the order of 30-110 years. Kodachrome II and -X films (1961-74) have about a half the stability of modern post-1988 Kodachrome. The Ektachrome films will fade in a range of about 16-25 years for an average 20 years; based on pp189-194 in Wilhelm & Brower (1993) and Kodak (1988). Unfortunately, Wilhelm used a single temperature when performing his accelerated aging tests, so he could not use the Arrhenius-plot method to project actual performance at lower temperatures. Kodak (1988) data does use the Arrhenius-plot method. Both groups of data, Kodak and Wilhelm (data), reflect the actual behavior of Kodak color films.

Cold Storage - Cool vs Cold vs Frozen

There are two types of cold storage vaults (1) Active - humidity-controlled cold vaults and (2) Passive – where materials are sealed in packages within free-zers. In the first, the artifact is easy to access, at a moments notice, but is many times (10-20) more expensive. The second method is far less expensive, but requires more time for access and warm-up.

Active humidity-controlled vaults cannot be cooled to as low a temperature as commercial freezers, thus they are often referred to as cool and cold storage vaults.

Cool = 45-60°F
Cold = 38-45°F
32°F = Water Freezes
Frozen = +25 to -25°F

Passive systems in commercial freezers (walk-in food storage "boxes") or consumer upright frost-free freezers require breaking the collection into small units, sealed bags. Commercial freezers (Bally Box type) are capable of 15-25° below zero (-25°F) or lower. Upright home-style freezers generally have a range of 25° F above zero (+25°F), to zero degrees, but not below zero. Small, under the counter sub-zero freezers are available for under $1000, but larger units run several thousand dollars for 20-40 ft^3.upright boxes. Obviously, the lower the temperature achieved the long the lifetime enhancement.

Active vs Passive Vaults

The Corbis-Bettmann Archives has invested in sub-zero passive storage (2004) using a sealed package system designed by Mark McCormick-Goodhart <http://www.wilhelm-research.com/pdf/WIR_IST_ColdStorage/WIR_ISTpaper_2004_04_HW.pdf>.

The Vancouver City Archives has developed a passive vault for their film collections. The process is detailed in publication **Cold Storage of Photographs at the City of Vancouver Archives**, Guidebook from Canadian Council of Archives, Sue Bigelow, 2004 which can be found at <http://www.wilhelm-research.com/canada/ccoa.html>.

The National Geographic Society has an immense slide collection in active vaults. They have several humidity controlled vaults scatter through out their many buildings, with more planned based on comments from Conservation staff in 2006. Other active vault users are the Library of Congress, the Museum of Modern Art and the National Archives and Record Administration (NARA). Active systems are favored by curators, registrars and staff in institutions that have large photographic print collections. Active systems are complex and expensive but they provide direct access to staff, usually through an abutting "cool room" that is held at a warmer temperature, regulated to a corresponding humidity. Warm up can be just a few hours in well designed systems. It is rumored that the vaults at the institutions mentioned cost over $1-5 million.

Table 8: Estimated Costs Passive or Active Systems

Cost	Size	Type of Cold Storage	Conditions
$300,000	20'x 20'	Active Vault -- Humidity Controlled	38°F and above
$30,000	20'x 20'	Passive Vault -- Walk-in Food Freezer	-25 to -15°F, sub-zero
$800	20 ft^3	Passive Freezer -- Frost-free Upright	0°F passive
$600	6 ft^3	Passive Freezer -- Frost-free Upright	-25°F passive

Active Vault

The active vault is and older style, based on the needs of large institutions of cold storage vault was an individually designed and built room that had both temperature and humidity control just above freezing 38°F. In humidity controlled vaults, the cold air must be humidity-controlled because the moisture in the artifacts is based on the moisture content of the surrounding air. Stable moisture content, and thus stable size, is a basic precept for all preservation measures.

In the humidity-controlled vault design the desirable traits of convenience and accessibility has been "traded for" high system complexity and cost with an overall decrease in artifact longevity. The convenience and accessibility help curators and workers who want instant access to specific transparencies or prints at a moments notice. For institutions with deep pockets and collections in good condition, these trade-offs seem reasonable.

Many Curators desire direct access to their artifacts without waiting for a 12-24 hour warm-up period. Direct access requires that the artifacts be housed in unsealed cabinets or boxes ready for retrieval and viewing at any time. Human comfort and mechanical logistics dictate that cold [38-50°F] or cool [45-60°F] temperatures be used in the walk-in humidity-controlled vaults, rather than frozen conditions [+25 to -25°F] used in high-longevity film storage systems.

In many humidity-controlled vault installations there is also a viewing-room that is maintained at a higher, but still cool, temperature at the identical humidity. This allows artifacts in the cold vault to be moved, still unwrapped, to a more comfortable space while maintaining artifact moisture content. In a cool room, the user needs only a modest sweater or light coat while viewing artifacts directly, all without a warm-up period. With a short warm-up within many anterooms the materials can be moved directly into the standard museum environment 70° ±5° at 50% RH ±10%.

Passive Vault

Food cold storage freezers operate a fairly stable low RH by default, but they are not humidity controlled. These vaults are called "passive" in the preservation field because the relative humidity (RH) is not directly controlled by the freezer equipment. The humidity is passively controlled by the sealed bags or gasketted cabinets, within the vault, where the moisture content can not change with the sealed bag regardless of the temperature. Passive systems can operate at much lower temperatures, extending the lifetime of its artifacts while also lowering the cost of operation. Finally, artifacts in seal bags or gasketted cabinets cannot be harmed by a system malfunction, external flood or excess water from a fire.

A passive vault operated at 0°F will cost about $1.25/ft^3/yr for electricity. A passive vault running at -15°F to -25°F will cost about $2-3/ft^3/yr (2006). The Wilhelm Imaging Research 15'x15'x7' passive vault (Grinnell, IA), cost approximately $550 to operate in 2004, where electricity cost was $0.63/kwh. The passive vault runs at about a third, to a quarter, the cost of humidity-controlled systems.

A humidity-controlled vault running at 40°F will cost about $4-6/ft^3/yr to operate. A15'x15'x7' vault will cost approximately $4000 to operate in 2006 in the Bay Area where electricity cost $0.75-0.85/kwh; the operating cost would be $5.50/ft^3/yr.

The standard 40°F humidity-controlled vault will have 1/38th (2.6%) the preservation effect of a sub-zero vault and cost 4-5 times as much to build and about 3-6 times more to run per year.

A passively controlled 0°F vault of the same size, will cost one quarter the amount to build (including the cabinets) and produce a 30-300 times improvement in stability, while affording more protection against equipment failure, acts of nature and fire damage.

Cold Storage of Small Quantities

A Sears' auto-defrost, 20 ft^3 cu ft, upright freezer ($800 delivered) can be used for storage at about 0°F. They also sell right off the store floor, a series of smaller chest-type manual-defrost freezers, ranging in size from 4 to 8 ft^3 (large TV to a desk in size) that can be used for smaller collections, priced from $180-350. The larger [20 ft^3] upright will cost about $50-100/yr ($3.75/ft^3) and the smaller will cost about $35-60/yr ($2.38/ ft^3).
Stand alone freezers have similar operating cost to the active humidity-controlled vaults, due to the lack of economy of scale for the freezers. A passive vault would run at about a third to a quarter the cost of operating upright freezers or active vaults.

Certain upright freezers (low temp freezers) are capable of -25°F, but the affordable units are the smaller under counter size holding 4-6 ft^3, rather than the 20 ft^3 of the normal 0°F upright <http://www.cooler-store.com/summit_upright_freezer_under_counter_1090_prd1.htm> and <http://www.cooler-store.com/summit_upright_freezer_low_temperature_1147_prd1.htm> . The purchase cost is about $1000, with $100-125/yr to operate. Larger 20-70 ft^3 low temperature upright freezers can be purchased for $4-12K. Installing a walk-in (Bally Box type) low temperature freezer makes better sense if portability is not an issue.

System Costs

A local institution built a small humidity-controlled vault (10'x10'x7' H) for $180K, or about $130K to $200K depending on location. If a cool (55-60°F) viewing-room were added, the project cost would increase by $60K-120K. The cost range corresponds to varying locations and configuration of the vault and construction variables. A $240K-300K vault would hold about 200-250,000 film artifacts at about $0.90 to $1.50 each. For the size indicated, the yearly utility cost would be $2000-3000, or $4 per ft^3 to operate.

The basic upright freezer [20 ft^3] can hold about 20,000 packaged negatives, and will cost $1000 for everything including packaging, or about $0.05 per film artifact. At $100 per year, operation is about $5/$ft^3$/yr.

The comparison is between (a) $0.05 per item for sealed package frozen storage and (b) $1 per item for a humidity-controlled vault. Besides the 20-times cost increase premium for the convenience of direct artifact access, the longevity of artifacts held at the relatively modest cold conditions will have about 40-300 times less permanence than those held under frozen conditions. In addition, when a humidity-controlled vault fails the results can be mold growth, envelopes stuck to the gelatin emulsion or high temperature base deterioration.

In a sealed package, within a commercial freezer, the slow warm up to room temperature at constant moisture content is the only adverse outcome from a system failure. Although, slow warm-up at constant moisture content is a intended procedure. When storage is parceled out into separate 20 ft^3-upright freezers, only the one unit that failed, not all the freezers, will cause problems. The resolution of the problem will require replacing only one freezer at about $800. On the other hand, a diagnostic visit for a custom built humidity-controlled vault will cost $1-3K, excluding parts and installation labor that could run several thousand dollars more.

Table 9: Estimated Construction and Running Costs

Temperature	Improvement	Construction Cost	Running Cost
70°F Humidity-controlled room	**normal rate**	**$5K - $10K**	**$4-6/ft^3**
40°F Humidity-controlled	**9 times normal rate**	**$80K - $320K**	**$25/ft^3**
0°F Passive Freezer	**350 times normal rate**	**$800 - $4K**	**$20/ft^3**
4°F Humidity-controlled	**350 times normal rate**	**$140K - $250K**	**$37/ft^3**
0°F Passive Vault	**350 times normal rate**	**$20K - $40K**	**$13/ft^3**
-15°F Passive Vault	**2000 times normal rate**	**$20K - $40K**	**$20/ft^3**
-25°F Passive Vault	**2500 times normal rate**	**$20K - $40K**	**$25/ft^3**
-25°F Passive Freezer	**2500 times normal rate**	**$600**	**$25/ft^3**

In upright freezers equipment failures do not result in high humidity, liquid water or high temperature. The moisture content of the materials contained in the sealed package will remain stable because the moisture has no place to escape and any stray liquid water is sealed out of the bag. The only issue in a freezer failure is a slow warm-up to "as sealed" conditions.

The "high temperature" failure mode is not possible in upright frost-free freezers, as shown in <http://www.appliance411.com/faq/howdefrostworks.shtml>. The "how it works" URL shows that excessive high temperature build up, due to freezer defrost coil overheat, has been designed out of the system using a series of elements that require multiple element failures for system failure. In an integrated system, such as a commercial upright freezer, multiple element failures generally cause a full system failure. The relevant design elements are: (a) specific fault-proof circuits [power for heater coil through compressor], (b) limited duration event timer [30-minute heater cycle] and (c) mechanical thermostats. Thus, failure of the defrost thermostat in an upright freezer will not result in internal overheating. The failure of the compressor will also prevent energizing of the defrost heater element. The refrigeration process may fail, but the artifacts are sealed in bags at constant moisture content as the cabinet slowly warms to room temperature, over several tens of hours. Any liquid water that may show up from melting ice will be sealed out of the bags.

In humidity-controlled walk-in vaults, where massive sub-systems are often interconnected rather that integrated, due to their shear scale, the loss of one subsystem can lead to overheating of the vault room. Overheating can have two outcomes (1) very high temperature or (2) elevated temperature resulting in humid air or liquid water. Liquid water can condense on cool artifact surfaces when humid air is created and artifacts are still below the dew point of the surrounding warmer air. The presence of liquid water will often lead to mold growth. Very high temperature, over prolonged periods, can also lead to faster deterioration of the film base, or dyes in color film.

For mold to grow, mold spores will settle on the artifact (going on all the time), either before or after the critical event. When the liquid evaporates from the growth media (paper or gelatin), the moisture content and pH may reach a critical point where mold will grow.

Overheating could be designed out of walk-in vault system with sufficient engineering experience. However, each of these 5- & 6-figure systems is a custom design. Thus, system integration relies on the refrigeration system experience of the designer, who probably has not designed, built or troubleshot one of these rare systems.

Warming within a humidity-controlled vault cannot be designed-out, only closely monitored and alarmed. In events where monitoring fails, water problem are inevitable. Mold growth can result, but often, the adverse outcome is sticking of the envelopes to the gelatin side of the film or plate. The fact that each artifact is unprotected in a humidity controlled vault, not in a sealed package, means that each can be harmed in any adverse water-based event.

Gasketted Cabinets for Passive Vaults

In passively controlled cold storage vaults some sort of "sealed" system is required. Sealed cabinets are one option. The cost of sealed cabinets range from

- **$1500 for a basic seal 6'x3'x14" standing storage cabinet with shelves**
- **$2500 for a 3' deep by 4' wide by 36" tall large flat material cabinets**
- **$3000+ for sealed flat-file storage cabinets**

Figure 4: Gasketted cabinets by Viking Metal Cabinet <http://www.vikingmetal.com/mus/search/348.html>.

The humidity of the air in the vault can fluctuate due to the opening and closing of the primary vault access door and time of the year. The gasketted cabinets and sealed bags maintain a stable humidity environment.

Figure 12. Freezer sharing work space.

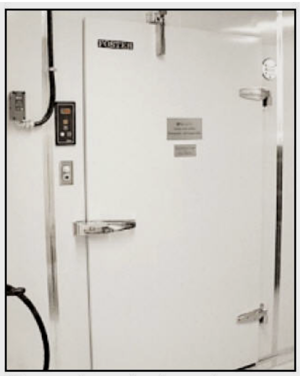

Figure 13. Freezer showing taped seams, alarm panel (read light).

Figure 14. CMI-packaged negatives in our walk-in freezer.

Figure 23. Cabinet loaded with 48 boxes.

Figure 5: The walk-in vault built at the City of Vancouver Archives showing both sealed packages stored on metal shelves and un-seal boxes stored in gasketted cabinets. Images have been taken from Sue Bigelow's 2004 report "Cold Storage of Photographs at the City of Vancouver Archives," **Guidebook from Canadian Council of Archives, which can be found at** <http://www.wilhelm-research.com/canada/ccoa.html>.

Freezer Kits

Metal Edge sells Safe-Care Image Archive Freezer Kits (800-336-4847) that consist of 2 heavyweight Ziploc bags (polyethylene) and a tan acid-free/buffered board box, with instructions for use. The cardboard box acts as the moisture sink and buffer; it is very high quality.

Equilibrate the materials at 65-72°F and 40-50% RH, for about a week, before sealing materials in the bag and placing in the freezer.

The bags can simply be removed from the freezer and allowed to warm up for 2-4 hours, while remaining sealed. For more degraded materials, and larger amounts, a slower warm-up procedure should be followed, see below.

Bags for Cold Storage

Average sized bag will hold about

- 2-4, 500-1500 ft reels per bag, with ample matboard, blotters or quality cardboard
- 50-200 sheets of 4 x 5 film in acid-free envelopes
- 50-100 sheets of 8 x 10 film in acid-free envelopes
- 10-20 slide protector pages (200-400 slides) per bag (double-bagged Ziploc bags)
- 6-12 video cassettes per bag, with ample matboard, blotters or quality cardboard
- 4-8 boxes of microfilm per bag
- Glass plates don't lend themselves to bag storage

See Gaylord Catalog (800-448-6160) and IMPAK Corp for ready-made bags and Metal Edge Inc. catalog (800-862-2228) for Freezer Kits.

Marvelseal 360 is a metalized polyethylene and polypropylene barrier film that is heat-sealable. It has a Nylon exterior that is slightly tougher than the Marvelseal 470. Escal bag material is a newer product that is clear. I have not used Escal, but it is getting favorable reviews. It is 4 times the cost of Marvelseal, but it's clear so you can see labeling inside; search online for sources.

A professional bag sealer should be chosen because the width of the seal is about ½", rather than the 1/8"-seam found in refrigerator bag sealers. The Futura Portable heat sealer, Barrier model, can be purchased for about $65 from (a) Audion Packing Aids Corp, San Rafael (415-454-4868), (b) one of the online suppliers of bagging supplies such as IMPAC Corp. At <http://www.sorbentsystems.com/footsealer.html> or (c) the conservation materials suppler selling the Marvelseal products.

Add 2-3 sheets of good-quality buffered 4-ply matboard (or 3/16" of buffered blotters, 4-5 sheets) to each bag, as a moisture sink. See the University Products (800-336-4847) catalog for cut-sizes of matboard. Materials should be labeled on the exterior of the storage bags. A label with actual contents is very helpful, but a unique number that is referenced in a nearby paper cataloged or online database is more efficient. The materials should be held in a controlled room that has a stable relative humidity, such as 40-45% for about 1-2 weeks before they are sealed into the storage bags. This will increase the life substantially over the average 65% RH conditions found in the Bay Area.

Warm-Up Process

When photographic materials are taken out of cold storage they must be allowed to warm to room temperature in a sealed bag before they are exposed to the unlimited water content of a room. Allow 6-12 hours for the "average" bag to adjust back to room condition before cutting seal (or opening the Ziploc bag), when held in a thermal barrier holder such as a Styrofoam cooler. Longer is required if there is a great deal of air, or film, in the bag. The bag should be warmed in a Styrofoam cooler to prevent temperature gradients. The Styrofoam "cooler's" thermal barrier prevents rapid warming of the bagged materials.

Shorter warm-up times can be use for tightly-conforming bags holding relatively small amounts of materials. The bag will need to sit on a rack in a well ventilated room. There will always be concert about warming too fast, but a 2-4 hour warm-up can be used in critical situations. The Styrofoam cooler method is recommended and preferred.

Time Out of Storage

Time out of storage (TOS) will decrease the useful life of materials in cold storage. IPI sells materials to figure TOS for (1) Color Film and (2) Acetate Base film. Basically, 5-days TOS per year (for sub-zero storage conditions) lowers life by 90% -- 0.1 x years = years with TOS. If the useful life starts at 1000 years it becomes 100 years, when using sub-zero cold storage.

Time out of storage of 5 days means the following:

- **(1) Someone requests a slide on Monday**
- **(2) Its taken out of the freezer for the 6-12 hour warm Monday evening**
- **(3) The user gets back to the slide Tuesday**
- **(4) They copy or use it on Wednesday**
- **(5) They give it back to the operator on Thursday**
- **(6) Sometime on Friday the operator reseals the slide's package and gets it back into the freezer**

All this assumes that the work area has consistent temperature and humidity, not requiring a preconditioning period.

Moisture Content and Relative Humidity in Cold Storage

Materials have a specific water content based on the humidity in the surrounding air. The equilibrium moisture content is the amount of water the material will hold in equilibrium with the relative humidity of (stable) air. If the relative humidity of the surrounding air changes, the moisture content of the material will come into equilibrium with the new RH of the air. The moisture content of cellulosic materials and gelatin, at 50% RH, is on the order of 5-8% of their gross weight.

Most cellulose-based materials reach 90% of equilibrium with a relative humidity change within 10-60 minutes, assuming a reasonable movement of air around the artifact. Complete (100%) equilibrium takes longer. Roll film and tightly packed negatives-in-envelopes take longer, days or weeks, to reach equilibrium in the center of the pack. If a material is sealed in a bag or cabinet within cold storage, the moisture content of the material remains almost the same as when it was at room conditions. The artifact's solid material is holding much more water by weight, than the air surrounding it. Thus, the artifact buffers the air. The air is almost inconsequential as long as some cellulosic is present. That is, the solid (cellulose) controls the gas (air) within the bag or sealed cabinet. If the material is slow to take-up or release moisture, a cellulosic buffer (matboard or acid-free blotters) is desirable. This is why matboard, acid-free blotters or acid-free envelopes are recommended when sealing film into bags for cold storage.

In a frozen state, it has been shown that sealed materials hold their moisture content, and, even slightly increase their moisture content. All materials will decrease in size very slightly when cooled, and will increase when warmed.

The significant point is that the sealed artifact is virtually stable, because stable moisture content means that the size of the artifact remains constant, based on moisture content which is the predominate influence on artifact dimensions. Constant moisture content during cool-down and warm-up is critical to the stability of materials in cold storage.

Upon cooling, air surrounding a material in a sealed bag will decrease its relative humidity. This is because materials hold "very" slightly more water at low temperature, than at room temperature. Materials hold less water at elevated temperature. This is

counter-intuitive to most in the museum professionals, because we know that air holds more water at higher temperature, and less water, at lower temperatures.
If the relative humidity in a bag/cabinet is 50% RH at room temperature, and there are hygroscopic materials in the bag/cabinet, then the air at -15°F is 35%. The small amount of air in the bag (or gasketted cabinet) has lower relative humidity, but the moisture content of the solid remains the same. Moisture content is the critical factor.

When the bag/cabinet is returned to room temperature, the moisture content of the material is the same as when it started, because no moisture could escape. The relative amount of moisture in the air has changed, but the absolute moisture content remains the same.

The relative humidity in the bag/cabinet never condensed at dew point because the amount of water in the "air" was limited by bag. As the air warms is can hold more water, so as the materials warm the air takes on the small amount of moisture given off by the solids and moisture buffer (cellulosic's such as matboard or blotters).

Constant Moisture Content Trapezoid
In Figure 6, below, the trapezoid labeled ***ABCD*** describes the boundaries of acceptable moisture content condition between room storage and "cold storage" conditions. The room conditions are 35-60 %RH, between 65-76° F, at the top, and 20-40 % RH and -25 °F.

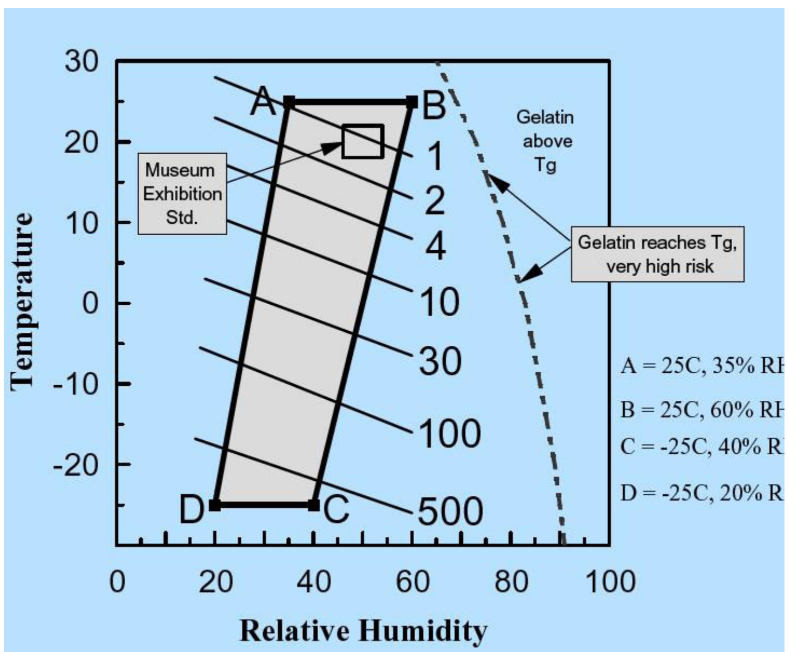

Figure 6: Trapezoid ABCD show the safe zone for the display and cold storage of photographic materials from work by Mark McCormick-Goodhart.

All photographic material must be equilibrated to these conditions prior to bagging and cold storage. Equilibration can take 1 hour for single items, to several weeks, for blocks of negatives in envelopes held in a group, in boxes. When the materials are frozen, they will stay within the ABCD trapezoid, because the moisture content at equilibration will be held constant by the storage bag or gasketted cabinet.

Figure 6 was taken from: McCormick-Goodhart, M. "The Allowable Temperature and Relative Humidity Range for the Safe Use and Storage of Photographic Materials," in Journal of the Society of Archivists, Vol. 17, No. 1, 1996 pp 7-21. Can be obtained from

SCRME, Information Services, Smithsonian Institution, 301-238-1240 Suitland, MD: Item #12891, or you can download his articles on cold storage from the Wilhelm research website <http://www.wilhelm-research.com/pdf/WIR_ISTpaper_2004_04_MMG/WIR_ISTpaper_2004_04_MMG_HW.pdf>.

If a material's temperature and humidity are kept inside the solid trapezoid found in McCormick-Goodhart's graph marked "Figure 4," the materials will follow line, ***H-I***, and will remain completely safe during the cooling down and warming up process. This is accomplished if a material is sealed within a bag, or gasketted cabinet, at 65-75°F and 35-62% RH, and then cooled to its storage conditions. The materials must warm-up also in the bag with its "sealed in" moisture content.

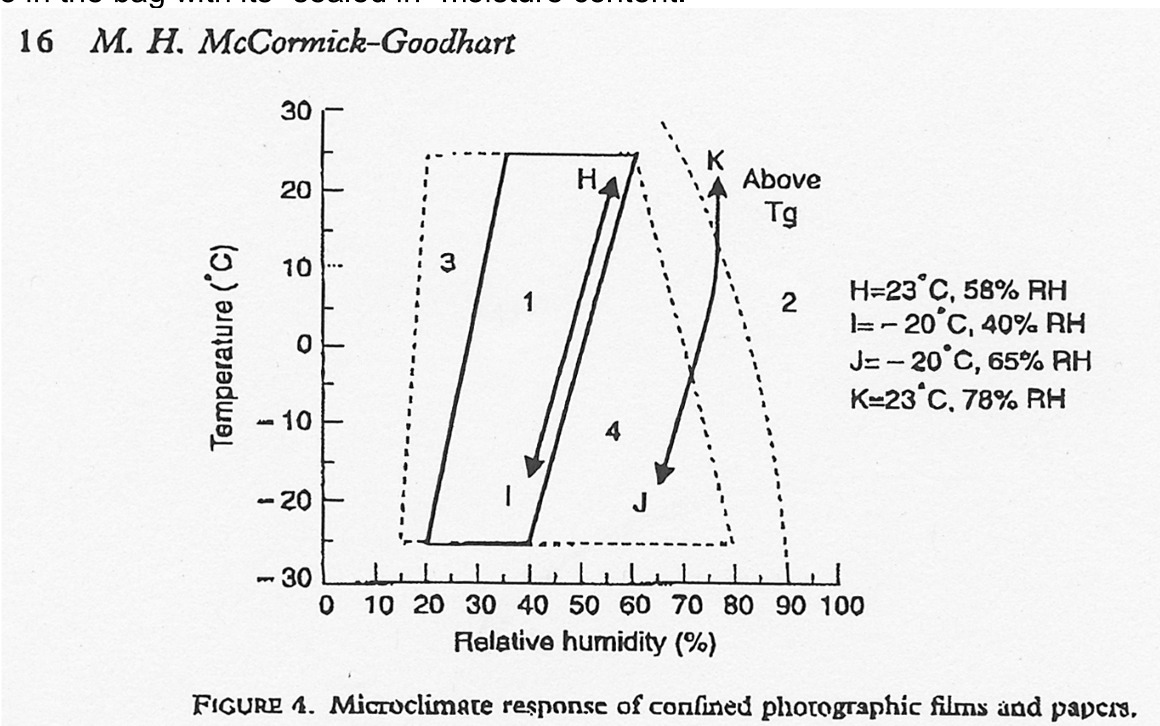

Figure 7: Figure 4 from "The Allowable Temperature and Relative Humidity Range for the Safe Use and Storage of Photographic Materials" by McCormick-Goodhart, p16.

If the material is removed from the bag, while still cold, it will follow the line, ***J-K*** outside the trapezoid. There will be two major results: (a) the materials could cross over the glass transition temperature (T_g) allowing the material to undergo an unacceptable size change (damage) and (b) condensation will form on the surface of the materials due to the massive amount of water in the surrounding air. Most new materials can tolerate some small number of these bad T_g cycles, but damage can occur at any time.

Physical Effects of Freezing

We often think of foods in the freezer, when we think of putting cultural materials into cold storage. Most foods held in the freezer (except things such as grains, nuts and dry pasta) have free water content. Free water freezes and expands when frozen. That is, the water is preset in large proportions, on the order of 20-100% or more, by weight of the solid. Water in cellulose and gelatin at 50% RH is on the order of 5-8% of the solid; there is no free water. Water held in materials at 50% relative humidity is adsorbed onto the surface as bound water. Bound water merely goes along with the other atoms in the materials as they increase and decrease in size with changes in temperature.

Free water freezes and expands when frozen, causing damage to thin cell membranes such a living or formerly living materials.

Every time we fly, we move in a complex metal, plastic, glass, paint and rubber structure from -70°F to -48°F, when flying at a 35-40,000 feet cruising altitude, back to 20°F to 100°F at ground level; a change of 70-170°F. The composite structure of the plane moves through the air at 400-600 mph ground speed, traverses massive temperature and pressure change all without the paint pealing or plastic and glass cracking.

Holding cultural material at room atmospheric pressure and at constant moisture content (in sealed containers within cold storage) has only small elastic effects on materials. The small change is size at different temperatures is fully recoverable, because it is "elastic" behavior.

System Design
Each system has to be designed specifically for the space to be used. The criteria are:
(1) Vault (room) or freezer
(2) Temperature
(3) Storage device (such as bags or cabinets)
(4) Materials to be stored
(5) Fire Protection requirements, locally

In practice, local fire rules or requirements are often the most difficult problems. For the construction and installation of a nitrate film cold storage vault at the Oakland Museum, the fire issues were the most difficult to resolve. For nitrate vaults, a cinderblock room needs to be built around the standard modular freezer room components. The Fire Marshal required that the vault must have sprinklers that would keep the freezer-room exterior cool in the event of a fire.

For the cold storage of normal film, a modular commercial freezer can be located in any larger room with no extra internal or external fire protection than that required within the specific building. A freezer project needs an experienced conservator who knows photographic materials and the cold storage options as a consultant.

Storage Materials and Solutions
For those materials of lower use priority they can be held singly, or in groups, within
- acid-free folders (Metal Edge)
- oversized folders made from acid-free/buffered paper (Permalife in Gaylord)
- oversized folders made from acid-free/buffered Tan Barrier Board (Gaylord)
- standard-sized large folders made from acid-free/buffered paper (Metal Edge)
- L-sealed Mylar folders of various sizes (Metal Edge)
- Mylar Document Protectors (Gaylord)
- self-made Mylar folders made from Mylar (0.003-0.005" thick) on the roll
- bulk in acid-free/buffered Archival Record Cartons (gray corrugated, Gaylord)
- bulk in Standard Record Storage Boxes (Metal Edge, Tan, buffered)
- within intellectual groups in Archival Document Cases (Tan, Lignin-free, Gaylord)

Foldered paper-base materials can be held in boxes such as
- acid-free/buffered Archival Record Storage Cartons (gray corrugated, Gaylord)
- Archival Document Cases (Tan, Lignin-free, Gaylord)
- Drop Front Storage Boxes (Metal Edge, Tan)

Books, pamphlets and notebooks can be held in
- Archival Document Cases of various sizes (tan, lignin-free, Gaylord) within

Document Preservation Binders (Gaylord)

- within Case Binders (Gaylord) using Glue-in attachment
- Individual Book Boxes (Metal Edge)
- Corrugated Book Storage Boxes (Metal Edge)

The most desirable option is the Archival Document Case, Individual Book Boxes and Corrugated Book Storage Boxes because they do not affect the artifact. One can glue-in Envelop Slings seen on Gaylord using Case Binders, for holding group of pages or other paper artifacts that are intellectually coherent.

Inner Housing – sleeves or interleaving (touching the artifact)
Inner housings protect the surface of a print or negative from damage when in a storage container. All historic images need surface protection such as sleeves, four-flap folders, page protectors (virgin polyethylene or poly propylene), or, single folders made from acid-free paper, buffered tissue, Permalife paper, acid-free glassine or polyester (Mylar).

Sleeves: In time, all existing Kodak triacetate sleeves should be replaced with acid free paper, glassine or polyester sleeves, envelopes or 4-flap paper folders.

Interleaving: Original prints held in groups within a single folder should be interleaved with some sort of acid free material such as acid-free glassine or tissue. The interleaving could be Permalife™ paper, buffered tissue, unbuffered tissue or glassine.

Glassine is generally my choice because it has minimal texture, is easy to handle, translucent and is now acid free (started about 20 years ago). Older glassine can be very acidic and should be eliminated from all collections.

1500 Park Avenue
Suite 132
Emeryville, CA 94608
510-594-8277 Off
510-594-8799 Fax

<http://briefcase.yahoo.com/tvitale@pacbell.net>
[Use of the above URL may require a "Yahoo! ID" to download files]

Albumen website (2001) <**http://albumen.stanford.edu/**>
VideoPreservation Website (2007) <**http://videopreservation.stanford.edu**>