USER'S GUIDE

FOR

A-D STRIPS®

FILM BASE DETERIORATION MONITORS

Awarded a Certificate of Technical Achievement in 1998 by the Academy of Motion Picture Arts and Sciences

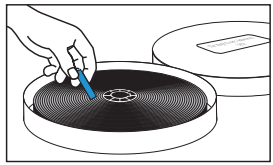
The Safe and Accurate Way to Check Film for Vinegar Syndrome

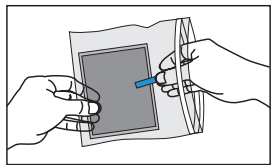
The development of A-D Strips® was made possible by funding from the Division of Preservation and Access of the U.S. National Endowment for the Humanities, the National Archives of Canada, the Canadian Council for Archives, and the National Film Board of Canada.

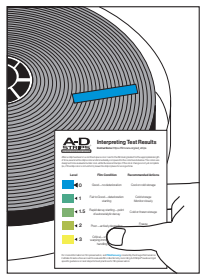
Made in USA Seventh Edition 1/22

Introduced in 1995, A-D Strips® have played an essential role in managing the preservation of acetate-based materials when used in combination with life expectancy predictive tools such as the IPI Acetate Storage Guide (1993) and the Storage Calculator for Acetate (2014, www.FilmCare.org). While A-D Strips are an easy-to-use, low-cost diagnostic tool, the information provided by this tool is invaluable for informing preservation planning and decision making that benefits the well-being of entire acetate-based collections.

BASIC INSTRUCTIONS FOR FILM TESTING







Important: Keep A-D Strips in the dark in a sealed plastic bag until ready to use.

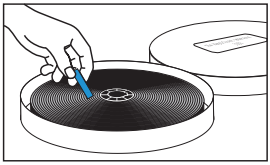
1. Open can, box, bag, or drawer containing film and lay an A-D Strip on top of film within. Reclose.
2. Wait for the length of time recommended for the temperature and RH conditions in the test area. (See Table I on page 7.)
3. Remove strip and immediately compare to color bands on reference card. Place strip directly on band for best color judgment.
4. Record the number of the reference band that most closely resembles strip. Enter results at www.FilmCare.org with a free account to evaluate your collection.
5. Discard A-D Strip after one use.

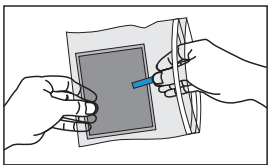
See pages 5-15 for more information.

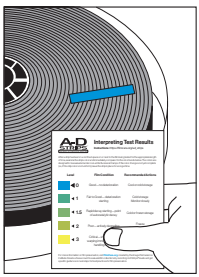
Interpretation (Acetate Roll and Sheet Films)

Level	Film Condition	Recommended Actions
0	Good - No deterioration	Cool/cold storage
1	Fair to good — Deterioration starting	Cold storage Monitor closely
1.5	Rapid degradation starting — point of autocatalytic decay (see figure on page 11)	Cold storage or freeze
2	Poor — Actively degrading	Freeze Copying advisable
3	Critical — Shrinkage and warping imminent; possible handling hazard	Freeze immediately Copy

INSTRUCCIONES BASICAS PARA EL TEST DE PELICULA







Importante: Conserve las A-D Strips en su bolsa de plástico bien cerrada. Abra la bolsa sólo cuando esté usted preparado para usar las tiras.

1. Coloque la A-D Strip encima del rollo de película y tape muy bien la caja, contenedor, o lata. Si se emplea una bolsa asegurese de cerrarla completamente.
2. Espere por el lapso de teimpo recomendado para las condiciones de temperatura y humedad relativa (RH) correspondientes al área donde se realiza el test. (Refiérase Tabla 1 en la página 7.)
3. Extraiga la tira del contenedor e inmediatamente con las bandas de color de la tarjeta de referencia. Coloque la tira directamente encima de la banda para un juicio más preciso del color.
4. Registre el número del color (en la tabla de referencia) que más se asemeje al color de la tira. Introducir los resultados en www.FilmCare.org con una cuenta gratuita para evaluar su colección.
5. Deseche las A-D Strips una vez usadas.

Para mayor información diríjase a las páginas 5 a 15.

Interpretación (Película de Acetato en Rollo y en Hojas)

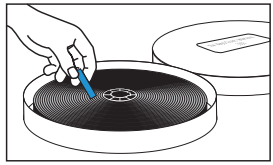
Nivel	Condiciones de la Película	Acciones Recomendadas
0	En buen estado - Sin deterioro	Almacenamiento fresco/frío
1	Regular a bueno - Inicio de deterioro	Almacenamiento frío Inspección continua
1.5	Inicio de degradación rápida - punto de deterioro autocatlítico (página 11)	Almacenamiento frío o congelamiento
2	Pobre - Degradando activamente	Congelar para preservar Se recomienda duplicar
3	Condiciones críticas - encojimiento, distorsión inminente. Posible riesgo para la salud durante su manejo	Congelar inmediatamente Duplicación inmediata

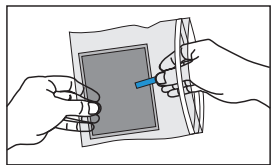
KURZANLEITUNG FÜR DAS TESTEN VON FILMEN

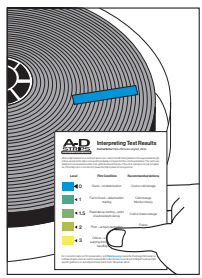
Wichtig: A-D Streifen bis zum Gebrauch in verschlossener Verpackung im Dunkeln aufbewahren!

1. A-D Streifen auspacken und auf das Filmmaterial in der Dose, der Schachtel, im Beutel oder in der Schublade legen; diese gut verschliessen.
2. Warten; Wartezeit entsprechend der Temperatur und Luftfeuchtigkeit im Testraum wählen. (Siehe Tabelle I, Seite 7.)
3. Streifen entfernen und sofort mit den Farbstreifen auf der Referenzkarte vergleichen. Legen Sie den Streifen für eine optimale Farbbeurteilung direkt auf das Band.
4. Die Nummer des mit der Farbe des Streifens am besten übereinstimmenden Referenzfarbbandes notieren. Geben Sie Ergebnisse bei www.FilmCare.org mit einem kostenlosen Konto, um Ihre Sammlung zu bewerten.
5. A-D Streifen nach einmaligem Gebrauch entsorgen.

Für weitere Informationen siehe Seiten 5–15.



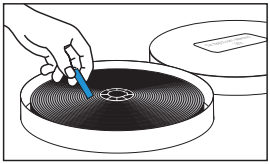


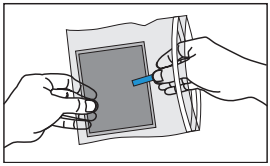


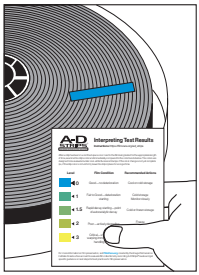
Auswertung (Azetat-Roll- und Planfilme)

Nummer	Zustand des Filmes	Empfohlene Massnahmen
0	Gut - Keine Zersetzung	Kühl- /Kaltlagerung
1	Mittelmässig bis gut - Beginnende Zersetzung	Kaltlagerung Sorgfältig überwachen
1.5	Beginnende schnelle Zersetzung - Autokatalytische Zersetzung beginnt (Seite 11)	Kaltlagerung oder Tiefkühlen
2	Schlecht - Schnell fortschreitende Zersetzung	Tiefkühlen Kopieren empfohlen
3	Kritisch - Schrumpfung und Wellenbildung bevorstehend; Handhabung kann Gefährdung für Filmmaterial darstellen	Sofor tiefkühlen Kopie anfertigen

MODE D'EMPLOI







Important: Conserver les A-D Strips à l'abri de la lumière dans une enveloppe plastique scéllée jusqu'à utilisation.

1. Ouvrir container, boîte ou enveloppe contenant le film et placer un A-D Strip sur le film. Refermer le contenant.
2. Attendre pour une duré e déterminée en fonction des conditions de temperature et HR (se reporter Table 1, page 7).
3. Retirez la bande et comparez-la immédiatement aux bandes de couleur sur la carte de référence. Placez la bande directement sur la bande pour un meilleur jugement de couleur.
4. Noter la référence correspondant le mieux à la couleur du papier indicateur. Entrez résultats à www.FilmCare.org avec un compte gratuit pour évaluer votre collection.
5. Ne pas réutiliser le papier indicateur.

Se reporter pages 5-15 pour des informations plus complètes.

Interprétation (plan-films et film en bobines sur support acétate)

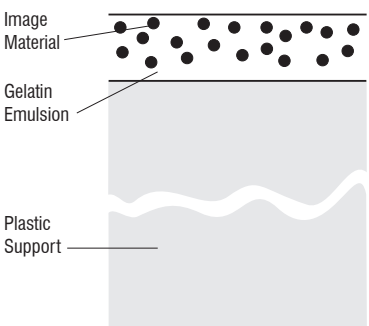
Niveau	Etat de conservation du film	Recommandations
0	Bon - Pas d'altération détectable	Stockage à basse température
1	Satisfaisant - Début d'altération	Stockage à basse température, contrôle périodique
1.5	Point autocatalytique du processus d'altération (voir figure page 11)	Stockage à basse température
2	Mauvais - Altération rapide	Congelation, reproduction conseillée
3	Etat critique. Rétraction et déformation du support imminentes; manipulation pouvant entraîner des altérations	Congelation et reproduction

ACETATE FILM BASE DETERIORATION—THE VINEGAR SYNDROME

Celluose acetate film is susceptible to a slow form of chemical decay known as the vinegar syndrome. This decay process causes plastic film base to become acidic, to shrink, and to give off the characteristic vinegary odor of acetic acid. Chemical reactions influenced by heat, moisture, and/or the presence of acidic vapors from nearby degrading film cause acid to be generated within the cellulose acetate support. From there it diffuses into the gelatin emulsion and often into the air, creating a sharp, acidic odor. The utility of A-D Strips is based on this phemonenon.

Although both nitrate and acetate plastics are prone to chemical decomposition, A-D Strips are *primarily designed for use with acetate film*. Their use with nitrate film requires further investigation (see page 8). Polyester plastic is much more chemically stable than acetate or nitrate plastics; A-D Strips do not provide useful information about the state of preservation of polyester film base.

Photographic film has three principal components: a support made of a sheet of transparent plastic, a gelatin emulsion, and an image of color dyes or metallic silver (see below). Three different types of plastic have been used in film manufacture to date: nitrate (from 1890 to 1950), acetate (from 1925 to the present), and polyester (from 1960 to the present).*



* For a full discussion of film history, identification of film type, film deterioration, and storage recommendations, see J. M. Reilly, *IPI Storage Guide for Acetate Film (*see Bibliography, p.16).

Research at Image Permanence Institute, Eastman Kodak Company, and Manchester Metropolitan University in the UK has contributed to a better understanding of film base deterioration. A bibliography of writings on film deterioration can be found at the end of this booklet.

What Are A-D Strips?

A-D Strips are acid-base indicator papers that turn from blue, through shades of green, and finally to yellow in the presence of increasing amounts of acid. (The A-D in the name stands for "acid-detecting.") The strips measure film deterioration indirectly by reacting to the amount of acidic vapor present in a confined air space around the film. After the strips are exposed, their color changes are compared to a color scale printed on the reference card provided in each package. This information can be used in judging the adequacy of existing storage conditions for film preservation and also for prioritizing films for duplication based on their

level of deterioration.

A-D Strips were created to aid in the preservation of collections of photographic film, including sheet and roll films, cinema film, and microfilm. They provide a *nondestructive* method of determining the extent of vinegar syndrome in film collections. The strips were developed specifically for acetate films, but they may also be used for testing other materials that release acidic compounds when they decay—for example, cardboard, adhesives, textiles, wood, and other materials commonly encountered in museum environments.[1] The A-D Strip color scale applies only to acetate, however; it will not give accurate quantitative results for other materials.

A-D STRIPS AND FILM COLLECTION PRESERVATION

A-D Strips are a diagnostic tool for vinegar syndrome. They can be used to determine the approximate extent of acetate support degradation in individual films, and they can also be used as a survey tool for gaining an overview of the condition of films in an entire collection. Using statistical sampling techniques, it is possible to obtain such an overview by testing the condition of only a small percentage of the total collection (see footnote 4 on page 12). Although it is often not possible or practical, testing every film in a collection and entering the data into a computerized database will produce a very accurate picture of the storage and duplication needs of a collection. Testing individual films whenever they are accessed is another approach. If A-D Strips are routinely used when a film is removed from storage for any reason, changes in condition over time can be monitored.

The Need for Proper Storage

A diagnostic tool like A-D Strips is only one part of managing the vinegar syndrome problem. The most important aspect of preserving acetate film is proper storage. *All* acetate and nitrate films, not just certain types or brands, are prone to degrade. The process of deterioration goes on every day, slowly or rapidly, depending on the temperature and relative humidity (RH) of the storage environment. Visit filmcare.org for interactive film storage calculators.

It is a simple fact of life that acetate film will begin to seriously degrade in about 50 years at room temperature and moderate RH. Periods of higher temperature and dampness will accelerate the process, and cold and dry periods will slow it down. Newly processed film stored in cool (less than 70°F/21°C) or cold (less than 50°F/10°C) conditions at moderate RH (20% to 50%) can be expected to last for centuries. Film stored under poor conditions may become degraded within a

[1] See Mary Kaldany, et al., "Evaluating the Stability of Commercially Available Artists' Coloring Materials Used to Create Compensation Infills for Losses in Textiles," *JAIC*, 38:3, Fall/Winter 1999, pp. 443-458 and Catherine Nicholson and Elissa O'Loughlin, "Screening Conservation, Storage, and Exhibit Materials Using Acid-Detection Strips," *Collections Caretaker*, a publication of the Northern States Conservation Center, 1:4, Winter 1998/1999, pp. 4-5.

few decades. Color film benefits doubly from cold storage: under cold conditions, not only is the film base stabilized, but the rate of color dye fading is minimized as well. Recommended storage conditions for photographic films can be found in the IPI Media Storage Quick Reference (see Bibliography p.16).

Overall management of the vinegar syndrome problem in a film collection involves knowledge of the deterioration process, the provision of a good storage environment, and the safe monitoring of film condition using A-D Strips.

Health Hazards Related to Degrading Film

Close contact with severely degraded acetate and nitrate films (touching or sniffing) may be a health hazard. Acetic acid and other acidic products emitted by degraded film have been known to produce contact burns, skin and mucous-membrane irritations, and other physiological effects. When handling degraded films, protective gloves and adequate ventilation are strongly recommended. Use of A-D Strips eliminates the dangers of "sniffing" degraded film and also provides a more objective and accurate determination of the presence of degradation products.

USING A-D STRIPS

Storage and Handling

A-D Strips will remain in good condition for five years after purchase if the heat-sealed outer package is not opened. It is recommended to store A-D Strips in a cool space and avoid storage above 25°C (77°F).

After opening, keep A-D Strips inside their resealable polyethylene bag and within the opaque outer bag when not in use. The strips should not be allowed to become too dry.

A-D Strips are somewhat light-sensitive; they will fade if exposed to room light for several days. The strips contain the dye bromocresol green, sodium salt. The dye is not toxic, but it is water- and alcohol-soluble and will run if it gets wet.

Use Conditions and Response Time

The time required for A-D Strips to reliably indicate the presence of acidic vapors varies with the acid level of the film and the ambient temperature and RH. At room temperature and moderate RH, the strips begin to change color within a few minutes when the film is very acidic. If film is less acidic more time is needed, but the change is usually complete in about 24 hours. Response time is slower at low temperatures or under dry conditions. A-D Strips may be used at or below freezing temperatures, but under such conditions

Temperature	Minimum Exposure Time
Room	24 hrs.
55°F/13°C	1 - 2 wks.
41°F/5°C	3 wks.
35°F/2°C	4 wks.
25°F/-4°C	6 wks.

Table 1. Recommended minimum exposure times for A-D Strips, based on temperature in testing area and moderate RH (30% to 50%).

users must allow more exposure time before reading the strip color. Table 1 suggests minimum strip exposure times based on climate conditions. (Of course, the goal in testing should be accuracy, not speed.) In order to establish the minimum exposure time required for a particular storage vault, the user might test a series of films at both room conditions and vault conditions to determine how long the exposure time must be in each case to achieve the same results. The resulting minimum exposure time can then be the standard practice for that particular vault.

Is There a Maximum Exposure Time?

Even at room conditions, strips may be left in contact with the material being tested for several weeks without compromising the results. However, if the strip is left inside the enclosure for several months, its color may shift and therefore may not give a true indication of film condition.

A-D Strips Currently Are Not Recommended for Use with Nitrate Film

Nitrate film degradation produces volatile nitrogen oxides, which are not immediately acidic in nature; they must react with oxygen and water before forming acids. In any case, the response of A-D Strips to degrading nitrate film can be slower than with acetate film, and the strips may show uneven color changes. If a color change does occur with nitrate film, it can be viewed as a reliable indicator of deterioration, but no change does not necessarily mean that the film is in good condition. Pending further research, IPI recommends using A-D Strips primarily for acetate film.

Use and Placement of Strips with Roll Films

A-D Strips should always be used inside a closed, confined space. Rolls of cinema film or microfilm can be evaluated in a closed can (vented or unvented), in a box, or in a plastic bag. Place a test strip on the film roll as shown in Figure 1. (Placing it on the reel will work, but the color changes fastest when the strip is placed

Figure 1. To test roll film in a can, place a strip on top of the film and reclose the can.

directly on the film.) The strip should not be placed under the film; it must be exposed to the atmosphere inside the confined space of the enclosure. Close the can, box, or bag and wait for the length of time recommended in Table 1.

As long as the minimum recommended exposure time is observed, materials can be tested *in situ.* This is a far more practical procedure than removing films to another area for testing and then returning them to storage, especially when many films are involved, as during a survey.

Cinema collections. A-D Strips may be used with both picture and magnetic track elements on acetate base. Interpretation for magnetic track film is similar to that for pictorial films.

Does the length of the film roll matter? In general, the mass of film being tested has little bearing on the accuracy of the reading. In a laboratory test, two rolls of the same film, one a 25-foot roll and one a 400-foot roll, enclosed in matching cans, gave identical readings after 48 hours at room conditions (a 400-foot roll holds sixteen times more film than a 25-foot roll). However, it has been observed that in cold conditions film mass may affect response time (the greater the mass of film, the faster the response of the strip). Also, in the extreme case of a very small roll of film inside a very large can, an inaccurate A-D Strip reading is possible. For testing a small mass of film that is stored in a large enclosure, it is better to place both the film and the strip inside a plastic bag.

Tips for Testing Sheet Film and Other Film Formats

Testing individual sheet films and amateur roll films (35mm, 120, etc.). Remove the sheet film from its enclosure and put a single sheet or a stack of several sheets of film inside a plastic bag, placing the strip directly on the film. Close the bag. Do not squeeze the bag flat, but allow some air space to remain around the strip. If sheet or roll films are already in plastic sleeves, strips can be placed inside the sleeves. A complete color change takes longer with a single sheet of film than with a roll of cinema film under similar test conditions. At room temperature, allow four days for single sheets.

Testing microfilm collections. For 100-ft. rolls of 16mm and 35mm microfilm, strips may be used inside cardboard boxes if desired, but more accurate measurements are obtained when the roll is removed from its box and placed in a plastic bag. Place the strip directly on the roll of film. For film in cassettes or cartridges, put the entire cartridge and the strip in a plastic bag.

A-D Strip Levels	Acetic Acid (ppmv*)
1	1 - 2
1.5	3 - 5
2	6 - 8
2.5	18 - 20

Table 2. A-D Strip levels and related amount of acetic acid in the air in parts per million.

**ppmv = parts per million (mL/m^3)*

Testing film in storage cabinets. A-D Strips can be used to detect the presence of acidic vapor in a film storage cabinet or in a box containing multiple films (see Figures 2 and 3). The cabinet or box must remain

Figure 2. To test films stored in a box, place strip on top of stack and reclose box.

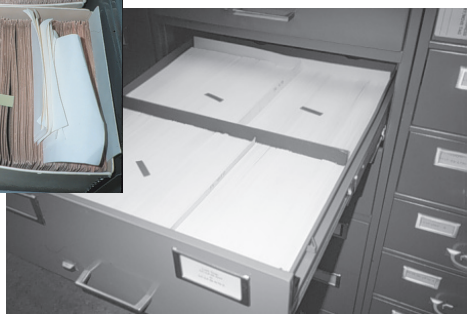


Figure 3. For film stored in a metal cabinet, strips are placed on top of film stacks and drawer is closed for the required exposure period.

closed while the strip is inside. The time required for a complete color change will be similar to that required for roll films and will depend on environmental conditions and the acid level present (see Table 1).

Testing room conditions. Used as a quick, short-term test, A-D Strips can provide a rough estimate of the level of atmospheric acidity in a storage area. Table 2 shows A-D Strip levels as they relate to the concentration of acid vapors in the air in parts per million (ppmv). This relationship was defined in the laboratory by estimating the concentration of acetic acid in the air inside pouches containing films at various stages of degradation using, simultaneously, Draeger diffusion tubes and A-D Strips. Tests were conducted at temperatures ranging from 20°C (68°F) to 5°C (41°F). The values are approximate, but they indicate a direct correlation between the two methods of measurement.

Evaluating and Recording Color Changes

After the strip has been in a confined space on or next to the film for the appropriate length of time, examine its color and immediately compare it to the color bands on the reference card. The color bands on the card are designed to be evaluated under cool-white fluorescent lamps. If the color change is not yet complete (i.e., if the strip color is not uniform), leave the strip in place for a longer time.

When no acidity is present, the strip remains blue. An increasing concentration of acid vapor turns the strip color gradually from blue to green and then to yellow; the lighter and yellower the color, the higher the acidity. In the presence of very high levels of acid, the strip turns bright yellow. The best color judgment is achieved when the strip is examined directly on or beside the card's color bands.

Because the strips change from blue to yellow on a gradual scale, in an infinite

number of steps, the strip color often does not exactly correspond to one of the four colors represented on the reference card. Use the following method to record your A-D Strip test results. If the color of the strip is fairly close to that of one of the color bands, record the number of that band. If the color of a strip falls between two of the bands, give it a number halfway between the two; for example, if the strip is not as blue as band 0 but not as green as band 1, record the level as 0.5. Thus, there can be seven possible color levels: 0, 0.5, 1, 1.5, 2, 2.5, and 3. If in doubt, between color levels, record the higher value. Using this standard notation will make it easier to gather statistics about a film collection.

Strip color should be evaluated promptly. The color reverts to blue very soon after removal from the confined space, and significant change can occur within a few minutes.[2] To preserve the color of the strips for later review, attach the strips to a sheet of clear plastic with clear plastic tape, being sure to cover the strips completely with the tape, and store the sheet in the dark. Strip color can be preserved for months in this way and improve the consistency of the readings in particular when several evaluators are surveying the collection.

Acetate films in good condition will generally turn the strips somewhat blue-green—somewhere between bands 0 and 1 on the reference card. This means they are doing well; they are in close to original condition and have a long life ahead of them. Green colors between levels 1 and about 1.5 indicate that there is some degradation, but it is not yet serious. This is a signal to watch the films more closely in coming years. Such films can still have a long life, providing they are stored in cold/frozen conditions.

At level 1.5 or greater, film is seriously degrading. Level 1.5 corresponds to an acidity value of around 0.5. This is the "autocatalytic point" that is the basis

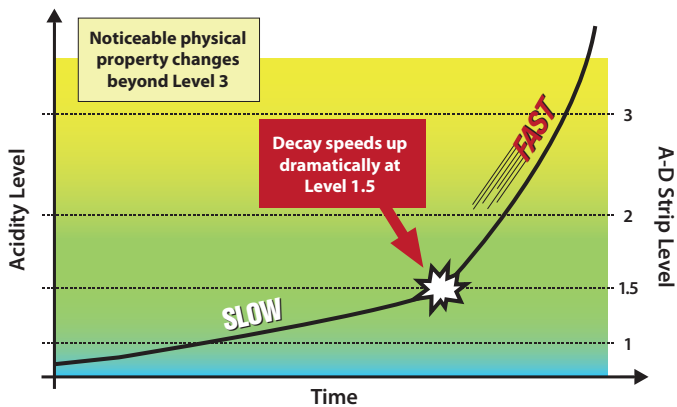


Figure 4. Relationship between A-D Strip levels, free acidity, and film condition.

[2] Even though the strips revert to a blue color after removal from a can, box, or bag, they should not be reused—they will not give an accurate reading a second time.

for predictions of life expectancy in the *IPI Storage Guide for Acetate Film*.

Although the majority of films at this acidity level are still quite usable, films that give a strip reading between levels 1.5 and 3 should be given priority for duplication and/or frozen storage. A-D Strip test results in this range should be strong incentive to improve storage conditions. Figure 4 shows the direct correlation between A-D Strip levels and the state of preservation of the film. Note that the curve becomes markedly steeper after it reaches the autocatalytic point, indicating the rapid increase in the rate of film decay.

A-D Strip Readings	Film Acidity (ml 0.1 N NaOH/g)
Level 0	0 to 0.1
Level 1	About 0.2
Level 1.5	About 0.5
Level 2	About 1
Level 3	About 2 or above

Table 3. A-D Strip levels as they relate to the amount of free acidity in acetate film.

Films that turn the strip yellow (i.e., level 3) are probably quite smelly already. These should top the priority list for duplication and immediate frozen storage before they warp or shrink irretrievably. Such films may also pose a handling hazard and should be treated with caution.

Correlation of A-D Strip Color Levels with Laboratory Tests

A-D Strip color levels relate to free acidity values as determined through laboratory tests, in which free acidity is expressed in milliliters of 0.1N NaOH per gram of film (see Table 3).[3] A-D Strips are semi-quantitative; they give an indication in line with the benchmarks listed in Table 3. NOTE: These benchmark acidity values for the color bands on the card apply to acetate films tested in a confined space.

SURVEY TECHNIQUES—STATISTICAL TREATMENT OF DATA

Recording a random sample of values, then calculating mean, standard deviation, and median, will help give an idea of the status of collections or subcollections.[4] After the data are recorded, a frequency histogram, like that shown in Figure 5, can be created. This is a helpful way to illustrate the distribution of vinegar syndrome within the sampled portion of a collection or collections. The data will be most accurate if the strips are consistently placed near the film, read on the same time schedule, and interpreted similarly. FilmCare.org provides a place to store and analyze survey data in order to implement a preservation strategy for film.

Monitoring the Condition of a Collection

Acetate base decay is a continuing chemical process; therefore, film condition should be rechecked periodically. How often a collection is rechecked depends

[3] See bibliography for P. Z. Adelstein, et al., "Stability of Cellulose Ester Base Photographic Film—Parts I and II."

[4] Described in B. Lavedrine, et al., "The Use of a Statistical Approach to Evaluate Accurately the Spread of the Vinegar Syndrome in a Large Collection."

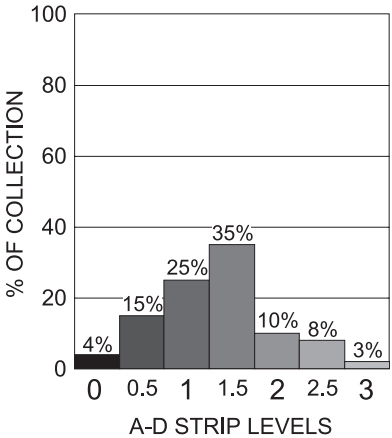


Figure 5. A frequency histogram showing the percentage of films in a test sampling at each of the seven possible levels (0, 0.5, 1, etc.).

Film Storage Temperature	How Often to Recheck
At or near room temperature (72°F/21°C)	At least every 2 years
Cool (less than 72°F/21°C)	At least every 5 years
Cold (50°F/10°C to 41°F/5°C)	At least every 10 years
Very cold or freezing (less than 41°F/5°C)	At least every 25 years

Table 4. Recommended monitoring frequency based on collection storage temperature.

partly upon the results of the initial survey and partly upon the environmental conditions in which the collection is stored. Table 4 provides some general guidelines for determining monitoring frequency, with the assumption that part of the collection has already started to decay (which is very likely) and is producing A-D Strip readings of around level 1.5.

What to Do With the Results

Be prepared to act on your survey results. It has been demonstrated that the only way to effectively minimize the decay of acetate collections is to provide suitable storage conditions. Just how urgently improved conditions are needed is dictated by the current condition of the film. A general outline of actions that can be taken based on film condition is provided in the table in the Basic Instructions section at the beginning of this booklet. These actions, briefly, are:

- Improve storage conditions. This is the most important action, and by far the most effective when cold storage temperatures are used.
- Prioritize materials for duplication. Materials in an advanced state of decay should be duplicated first.
- Periodically recheck the condition of the collection (see Table 4). Monitoring the condition of collection materials enables collection managers to take proactive measures when necessary.

Improve Storage Conditions—By How Much?

Providing better storage conditions has the greatest potential to postpone further deterioration of acetate materials. Prioritizing duplication is often impractical for large collections. Collection stewards can use A-D Strip survey results together

with IPI's Storage Calculator for Acetate (available at www.FilmCare.org) to predict the evolution of a collection's condition depending on temperature and RH conditions and inform preservation planning and decision making.

The Storage Calculator for Acetate estimates the effects of temperature (T) and relative humidity (RH) on fresh and degraded acetate film. Fresh acetate refers to acetate film newly processed, and degraded acetate refers to acetate film at the onset of vinegar syndrome (A-D Strip level of 1.5). Users can input the current T and RH storage conditions into the calculator and generate an estimate for the direct impact of those conditions on the chemical stability of acetate materials. Figure 6 illustrates a scenario where the collection is stored at 68°F (20°C) and 50% RH. At those room temperature conditions fresh acetate would reach the onset of vinegar syndrome within 50 years. More alarmingly, film already in that condition (A-D Strip level 1.5) would reach very poor condition within only 6 years. This demonstrates that at those environmental conditions, any acetate collection containing a significant portion of materials displaying an A-D Strip level of 1.5 would be at great risk for loss of materials in a very short period of time. Under these circumstances, improving the storage environmental conditions is the only option to address the long-term preservation of the collection.

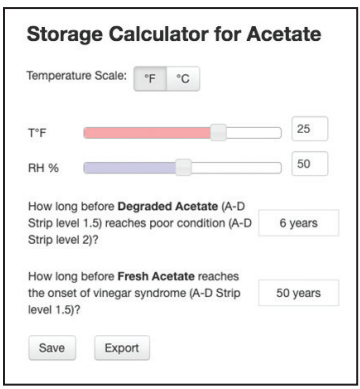


Figure 6. IPI's Storage Calculator for Acetate (available at www.FilmCare.org).

Temperature°F	Humidity	Degraded Acetate Years	Fresh Acetate Years
25	50	167	1280
40	50	49	405
68	50	6	50

Figure 7. Using IPI's Storage Calculator for Acetate, collections care professionals can estimate the impact of storage temperature on acetate film stability. This table illustrates how lower temperatures can postpone acetate deterioration, and that degraded acetate requires a lower storage temperature than fresh acetate.

While the ultimate decision on how to improve environmental conditions will depend on a variety of factors, the evaluation of the impact of various temperature and RH conditions on acetate stability constitutes the essential first step in informed decision making. The Storage Calculator for Acetate enables collection stewards to assess the benefits and risks of different storage environments for acetate-based materials and can be used independently to quantify the potential of lower storage temperatures (Figure 7).

It is recommended that users focus on the behavior of "degraded acetate" to ensure the best possible benefit across an entire collection. Data collected by IPI for de-

graded acetate materials stored at subfreezing temperatures for twenty five-years demonstrates that chemical deterioration is stabilized at subfreezing temperatures.

THINGS TO WATCH OUT FOR

Acetic acid vapors are volatile; if they were not, A-D Strips would not work. But this volatility means that acidic vapors from degrading film can readily be absorbed by storage enclosures and by other film. For example, high levels of acidity can be measured inside paper envelopes or cardboard microfilm boxes that formerly contained very degraded film, even after the film has been removed. (Plastic bags, too, can absorb acidity and retain it. Bags that have housed degraded films for testing with A-D Strips should not be reused.) Absorbed acidity in a box, bag, or envelope dissipates with time, but a small amount always remains.

Likewise, "good" (undegraded) film can absorb acidity from its deteriorated neighbors inside a box or cabinet. This is harmful, because the absorbed acidity will speed the degradation of the good film.

The ability of film to absorb acid vapors also means that even polyester films sometimes can be acidic. Because of their greater chemical stability, these films probably are not in much danger from the absorbed acidity. It would therefore be a waste of resources to duplicate polyester film that has absorbed acid vapors, because polyester is less threatened by acidity than acetate is. (Acidity *does* have a detrimental impact on the stability of color dyes, however.) It is always advisable to identify the film type as acetate, nitrate, or polyester before taking any actions based on the use of A-D Strips. Post-1960s microfilm and sheet film collections are the ones most likely to have a close intermixing of acetate and polyester films. A simple way to identify polyester film is to use crossed polarizers (see the *IPI Storage Guide for Acetate Film* for more information).

The volatility of acetic acid vapors also means that acidity can evaporate from film over time, so that testing with an A-D Strip sometimes reveals a relatively moderate level of acidity despite the fact that the film is obviously very buckled and degraded. One does not need an A-D Strip to know that film in this condition is deteriorated. This phenomenon is observed mostly in sheet films that have been handled a great deal.

BIBLIOGRAPHY

Books, Articles, and Reports

Adelstein, P. Z., "From Metal to Polyester: History of Picture-Taking Supports," *Pioneers of Photography*, Eugene Ostroff, ed., Springfield, Virginia: Society for Imaging Science and Technology, 1987, pp. 30-36.

Adelstein, P. Z., *IPI Media Storage Quick Reference*, Rochester, NY: Image Permanence Institute, Rochester Institute of Technology, Second Edition, 2009. https://s3.cad.rit.edu/ipi-assets/publications/msqr.pdf

Adelstein, P. Z., J. M. Reilly, D. W. Nishimura, and C. J. Erbland, "Stability of Cellulose Ester Base Photographic Film: Part I—Laboratory Testing Procedures," *SMPTE Journal* 101(May 1992): 336-346.

Adelstein, P. Z., J. M. Reilly, D. W. Nishimura, and C. J. Erbland, "Stability of Cellulose Ester Base Photographic Film: Part II—Practical Storage Considerations," *SMPTE Journal* 101 (May 1992):347-353.

Adelstein, P. Z., J. M. Reilly, D. W. Nishimura, and C. J. Erbland, "Stability of Cellulose Ester Base Photographic Film: Part III—Measurement of Film Degradation," *SMPTE Journal* 104 (May 1995): 281-291.

Adelstein, P. Z., J. M. Reilly, D. W. Nishimura, C. J. Erbland, and J.-L. Bigourdan, "Stability of Cellulose Ester Base Photographic Film: Part V—Recent Findings," *SMPTE Journal* 104 (July 1995): 439-447.

Adelstein, P. Z., J. M. Reilly, and F. G. Emmings, "Stability of Photographic Film: Part VI—Long-Term Aging Studies," *SMPTE Journal*, (April 2002): 136-143.

Allen, N. S. and M. Edge, "Initiation of the Degradation of Cellulose Triacetate Base Motion Picture Film," *Journal of Photographic Science* 38 (2): 54-59.

Allen, N. S., M. Edge, J. H. Appleyard, T. S. Jewitt, and C. V. Horie, "Degradation of Historic Cellulose Triacetate Cinematographic Film: Influence of Various Film Parameters and Prediction of Archival Life," *Journal of Photographic Science* 36 (6):194-198.

Bigourdan, J.-L., "Stability of Acetate Film Base: Accelerated-Aging Data Revisited," *Journal of Imaging Science and Technology* 50 (5): 494-501, 2006.

Bigourdan, J.-L., "Vinegar Syndrome: An Action Plan," *The Vinegar Syndrome, A Handbook: Prevention, Remedies, and the Use of New Techniques*, Bologna: The GAMMA Group, 2000.

Bigourdan, J.-L., "Preservation of Acetate Base Motion-Picture Film: From Stability Studies to Film Preservation in Practice," *The Vinegar Syndrome, A Handbook: Prevention, Remedies, and the Use of New Techniques*, Bologna: The GAMMA Group, 2000.

Bigourdan, J.-L., P. Z. Adelstein, and J. M. Reilly, "Use of Microenvironments for the Preservation of Cellulose Triacetate Photographic Film," *Journal of Imaging Science and Technology* 42 (2): 155-162.

Bigourdan, J.-L., and J. M. Reilly, "Effectiveness of Storage Conditions in Controlling the Vinegar Syndrome: Preservation Strategies for Acetate Base Motion-Picture Film Collections," M. Aubert and R. Billeaud, eds., *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium*, *Proceedings of the Joint Technical Symposium, Paris*, (2000): 14-34.

Bigourdan, J.-L., and J. M. Reilly, *Environment and Enclosures in Film Preservation*, Final Report to the Office of Preservation, National Endowment for the Humanities, Grant # PS 20802-94, Rochester, NY: Image Permanence Institute, 1997.

Brems, K. A. H., "The Archival Quality of Film Bases," *SMPTE Journal* 97 (December 1988): 991-993.

Edge, M., N. S. Allen, T. S. Jewitt, J. H. Appleyard, and C. V. Horie, "The Deterioration Characteristics of Archival Cellulose Triacetate Base Cinematograph Film," *Journal of Photographic Science* 36 (6): 199-203.

Edge, M., N. S. Allen, T. S. Jewitt, and C. V. Horie, "Fundamental Aspects of the Degradation of Cellulose Triacetate Base Cinematograph Film," *Polymer Degradation and Stability* 25 (1989): 345-362.

Fordyce, C. R., "Motion Picture Film Support: 1889-1976, An Historical Review," *SMPTE Journal* 85 (July 1976): 493-495.

Horvath, D. G., *The Acetate Negative Survey,*

Louisville, Kentucky: Ekstrom Library, University of Louisville, February 1987.

Jenkins, R. V., *Images and Enterprise, Technology and the American Photographic Industry 1839 to 1925* Baltimore: The Johns Hopkins University Press, 1975.

Kopperl, D. F., and C. C. Bard, "Freeze/Thaw Cycling of Motion-Picture Films," *SMPTE Journal* 94 (August 1985): 826-827.

Lavedrine, B., R. Duverne, M. Leroy, M. Aubert, and J.-L. Cot, "Analyse statistique de l'état de conservation d'une collection de films sur support en triacetate de cellulose," M. Aubert and R. Billeaud, eds., *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium*, Proceedings of the Joint Technical Symposium, Paris (2000): 44-53.

Mees, C. E. K., "History of Professional Black-and-White Motion-Picture Film," *Journal of the Society of Motion Picture and Television Engineers* 63 (October 1954): 125-140.

Ram, A. T., "Archival Preservation of Photographic Films—A Perspective," *Polymer Degradation and Stability*, 29 (1): 3-29.

Ram, A. T., D. F. Kopperl, R. C. Sehlin, S. Musary K. Morris, J. L. Vincent, and P. Miller, "The Effects and Prevention of the 'Vinegar Syndrome,'" *Journal of Imaging Science and Technology* 38 (3): 249-261.

Ram, A. T. and J. L. McCrea, "Stability of Processed Cellulose Ester Photographic Films," *Journal of the Society of Motion Picture and Television Engineers*, 97 (June 1988): 474-483.

Reilly, J. M., *IPI Storage Guide for Acetate Film*, Rochester, NY: Image Permanence Institute, Rochester Institute of Technology, 1993. https://s3.cad.rit.edu/ipi-assets/publications/acetate_guide.pdf

Reilly, J. M., P. Z. Adelstein, and D. W. Nishimura, *Preservation of Safety Film*, Final Report to the Office of Preservation, National Endowment for the Humanities, Grant # PS-20159-88, Rochester, NY: Image Permanence Institute, Rochester Institute of Technology, March 1991.

ANSI and ISO Film Storage Standards

American National Standard for Imaging Media—Processed Safety Photographic Film—Storage, PIMA IT9.11-1997, revision and redesignation of ANSI/NAPM IT9.11-1993, (New York, American National Standards Institute, 1997).

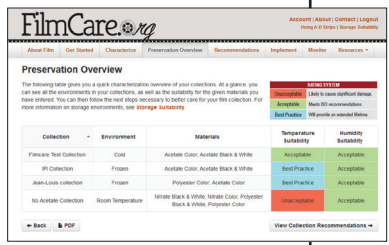
ISO 18911: 2010 Photography—Processed Safety Photographic Films—Storage Practices, formerly ISO 5466, (Switzerland, International Organization for Standardization).

THE IMAGE PERMANENCE INSTITUTE

The Image Permanence Institute® (IPI) is a university-based research center in the College of Art and Design at Rochester Institute of Technology (RIT) dedicated to supporting the preservation of cultural heritage collections in libraries, archives, and museums around the world.Proceeds from the sale of A-D Strips go toward the continuation of preservation research at IPI.

FilmCare.org

Funded by the National Endowment for the Humanities, FilmCare.org is a central resource for best practices in film preservation that provides guidelines for dealing with the preservation of all types and formats of film materials. It addresses the requirements for preserving black-and-white and color film and nitrate, acetate, and polyester-based film. It also addresses specific issues for motion-picture film, sheet film, still roll film, microfilm, and aerial film, as well as the management of collections containing a variety of media types (certainly the most common real-life situations encountered in the field). This approach focuses primarily on storage, condition surveys, and the development and implementation of best-fit environment-based strategies. Users can create a FREE account to evaluate their own collections by recording A-D Strip levels and get specific guidance on next steps for best practices for film preservation.



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