Appendix M: Management of Cellulose Nitrate and Cellulose Ester Film

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Appendix M: Management of Cellulose Nitrate and Ester Film

A. Overview

1. *What is cellulose nitrate (nitrate)?*

Nitrate refers to a group of early transparent plastic film supports that were most common between 1910 and 1950. Created as an easy-to-handle replacement for heavy and awkward glass plates, gelatin film, and paper negatives, nitrate film was used for still photographic negatives and transparencies, as well as motion picture film. Most nitrate film consists of a flexible sheet or roll of cellulose nitrate (nitrate) film base with a silver gelatin photographic emulsion (image bearing layer) on top. During the 20th century, amateur and professional photographers and filmmakers used nitrate more frequently than any other film support to hold the emulsions of their negative and film images.

Cellulose nitrate polymers, initially called gun cotton, were first synthesized over 150 years ago for use in the manufacture of military explosives. Later, cellulose nitrate polymers were treated with camphor to produce some of the earliest plastics. Celluloid, an early plastic replacement for ivory, was made into hairbrushes, billiard balls, toys, and a variety of home products. In the late 1940s, cellulose nitrate lacquers, adhesives, and metal coatings became popular, many of which are still in common use today. More recently, printing inks; plastics; coatings for stone, metal, and ceramics; and common adhesives, such as DUCO Cement and UHU All Purpose Clear Adhesive, have used cellulose nitrate polymers. Cellulose nitrate polymers vary in the amount of actual cellulose nitrate in their composition, from collodion photographic emulsions with a 10.5% concentration, to photographic flexible film bases with a 12% concentration, to explosive weapons-grade gun cotton with a 12.5% concentration.

If deteriorated, nitrate may be yellowed, tannish, stained, bleached, sticky, brittle, blistered, pungent-smelling, or powdery, depending upon the stage of deterioration. Nitrate photographic film has sometimes been called:

- celluloid
- nitrocellulose
- flammable film
- pyroxolin
- flam film
- cellulose nitrate

Nitrate is often confused with the cellulose ester films, including acetate, diacetate, and triacetate negatives, which deteriorate in a similar fashion. Cellulose ester films are described in Section B.1. Paper-based photographs are **never** nitrate. Specific tests have been developed to identify nitrate.

See Section B.6 below for more information on these tests. The modern replacement for nitrate and acetate films is polyester, a stable plastic.

2. *What are nitrate photographic negatives and transparencies?*

In the United States, nitrate-based still photographic negatives and, less commonly, positive transparencies were produced between 1889-1950. Both amateur and professionals photographers used nitrate film for fine art photography, photojournalism, portraits, travel photography, and technical photography such as aerial, dental, legal, and medical photographs (both X-ray and standard negative and transparency images). Manufacturers such as Agfa, Ansco, Defender, DuPont, Hammer, and Kodak produced nitrate films. See Table 1 (Section A.4) to learn when different formats and types of nitrate still negatives were first introduced or last available in the U.S.

The earliest nitrate film (1889-1903) has a thin (<8/1000 of an inch or <8 mil) nitrate film base and gelatin coating on only one side; therefore it tends to curl. This earlier film is more stable than later professional film, which has a thicker nitrate base (8 mil) to keep the film flat during processing. Professional negatives are the least stable of the still negatives. On occasion, rolls of 35mm-nitrate still negative film are confused with motion picture film when the roll film remains in its original roll format. Roll films may be identified by their frame numbers, which motion picture films lack. Nitrate sheet and cut film have a border pattern (frame-like edge) that doesn't occur consistently around the image. On the long edge of the film, the border ends about an inch from the end of the image, while the image reaches to the film edge in this area.

Most nitrate still images are flat sheets of transparent flexible film containing negative or positive photographic images in a wide variety of sizes (formats) from 35mm to greater than 16" x 20". Included in this category are:

- ***aerial film*** (ranging in size from 4" x 5" to 8" x 10"), which is easily identifiable by subject content

- ***X-ray film*** (emulsion coated on both sides of the base), which is also easily identifiable by subject content

- ***film packs*** (up to 5" x 7"), which are recognizable by the lightweight film base, a wide short-edge border (frame-like edge of the image) and thinner long-edge border, and the adhesive or paper residue from a pull tab that may be present on the short border.

3. *What is nitrate motion picture film?*

Nitrate motion picture film consists of varying length strips of flexible film with perforations along both side edges, which allow the film to be fed through a camera, projector, or film editor. Unlike slides and negative roll film, however, the motion picture film frames have no sequential frame numbers. Nitrate motion picture film was used to create educational film strips, amateur films, training films, travel films, and amateur and commercial motion picture releases, both silent and with sound.

Nitrate motion picture film can contain positive or negative motion picture images. These images may be either color or black and white, generally showing motion in sequence from left to right like a comic strip. Most nitrate motion picture film is thinner than negative film but relatively less stable as it is stored tightly rolled and in large quantities, which hastens deterioration.

Nitrate motion picture film was originally available between 1895 and 1951. These nitrate motion picture film availability dates are not absolute, however, as some filmmakers had stockpiles of this film and continued to use it for some years. See Table 1 below for precise dates when specific types of nitrate stopped being manufactured in the U.S.

4. *When was nitrate used in the United States?*

American amateur and commercial still photographers used nitrate-based film most frequently between about 1908-1939, although nitrate film was available between 1889 and 1951. Specific dates vary for some gauges and formats (X-ray, aerial film, and roll film). The history of nitrate and other film types produced in the U.S. is chronicled below.

Table 1: A History of Nitrate Film
1889 – Nitrate film is developed for roll film (not 35mm), sheet film, film pack film, X-ray film, and professional 35mm motion picture film.
1895 – Nitrate commercial motion picture film is available.
1900 – Nitrate motion picture film becomes commonly available.
1903 – Nitrate film is given a thicker nitrate film base and a gelatin backing on both sides.
1908 – Kodak introduces cellulose acetate “safety” roll film negatives for still cameras.
1909 – The National Board of Fire Underwriters develops rules for nitrate handling and storage.
1920 – Nitrate 35mm roll film and aerial film are available.
1920 – Acetate amateur motion picture film is available in 8mm and 16mm formats.
1920 – Nitrate negative film commonly replaces glass plate negatives.
1923 – Kodak introduces cellulose acetate amateur motion picture film.
1925 – 35mm nitrate still negative film begins to be available and cellulose acetate film becomes much more common.
1930 – Acetate sheet film, X-ray film, and 35mm roll film become available.
1933 – Last year Kodak manufactures nitrate X-ray film in the U.S.
1935 – Nitrate still negative film begins to be replaced by cellulose acetate “safety” film.
1937 – Cellulose acetate film begins to be replaced by cellulose diacetate.
1938 – Last year Kodak manufactures 35mm nitrate still negative roll film in the U.S.
1939 – Nitrate still negative film is largely replaced by “safety” films.
1939 – Last year Kodak manufactures portrait and commercial sheet nitrate film.
1940 – Acetate aerial film and roll film (other than 35mm) is developed.
1942 – Last year Kodak manufactures aerial nitrate film in the U.S.
1947 – Cellulose diacetate still negative film begins to be replaced by cellulose triacetate.
1948 – Kodak introduces triacetate motion picture films. *Note***:** If your print is edge marked “safety,” it dates after 1948.
1949 – Triacetate motion picture films are now in common use.

1949 – Last year Kodak manufactures nitrate film packs in the U.S.

1950 – Last year Kodak manufactures roll film in sizes 616, 620, and 828 in the U.S.

1950 – Acetate film pack and professional 35mm motion picture film become available.

1951 – Last year Kodak manufactures professional 35mm motion picture film in the U.S.

1951 – After this date, all camera negative separation films (Technicolor camera negatives, master positives, matrices, and release prints) are produced in triacetate. Most film produced before this date in the U.S. is unstable.

1960 – Polyester sheet film, X-ray film, and aerial film become available.

1960s– During this decade, most Technicolor™ films are on polyester support matrix films.

5. *Why should I be concerned about nitrate film?*

As it deteriorates, nitrate gives off highly acidic nitrogen oxide gases, particularly nitric oxide, nitrogen dioxide, and others, which either escape into nearby areas—threatening staff, buildings, and collections—or stay captured in the sealed storage area. Unless allowed to escape, these gases build up, causing an autocatalytic reaction that speeds decomposition of the original nitrate materials. Since the reaction produces heat, which further acts on the available gases and humidity, the environment around the nitrate rapidly becomes toxic. Nitrate poses a variety of problems, including:

- ***Health problems*:** All nitrate film deteriorates naturally over time, unless kept in very cold storage. Deteriorating nitrate film gives off gaseous byproducts, including nitrate oxide and nitrogen dioxide gases, which may threaten researcher and staff health. Health threats include:

  – eye irritation

  – headaches

  – nausea

  – rashes

  – respiratory irritation

  – skin irritation

  – swollen glands

  – vertigo

  All human exposure to nitrate should be limited in duration and monitored for side effects. Staff working with nitrate must keep track of and limit the number of hours of exposure and use special equipment when working with nitrate. See Section C.7 for details.

- ***Safety problem*:** As nitrate decomposes, it releases heat (an exothermic reaction) and acidic gases, including nitric oxide and nitrogen dioxide. In the presence of high humidity or water vapor, the nitrogen dioxide deterioration byproducts can produce nitric acid, a very corrosive compound. Large quantities of nitrate, particularly bulk quantities of roll film (20,000 linear feet or more), motion picture (20 films or more), or X-ray film (875 X-rays or more than 75 pounds), when housed together, will deteriorate at an ever-accelerating rate due to the build up of heat and acidic gas deterioration byproducts. See Section C.7 for guidance on how to work with nitrate.

If you store quantities of deteriorated nitrate, it may spontaneously ignite at temperatures of 100°F (38°C) or higher. Undeteriorated nitrate ignites at about 266°F (130°C). **Burning nitrate produces toxic gases, such as carbon monoxide and nitrogen peroxide that pose a severe threat to life.** These toxic gases have killed many individuals in theaters, clinics, and storage structures. In 1929, gases from burning X-rays during a clinic fire in Cleveland killed 125 people.

Since nitrate contains chemically combined oxygen, it produces its own oxygen as it burns. Once burning, nitrate roll film or motion picture film is almost impossible to extinguish as the center of the film burns at the same speed as the exterior due to the nitrate's ability to use the chemically combined oxygen. Nitrate is a serious threat to the safety of all people that work in the same building, all collections stored in the building, and all historic structures nearby. Nitrate can burn in a closed film can, under water or sand, and despite modern fire suppression systems including dry chemical and foam fire extinguishers, halon, carbon dioxide fire systems, and similar extinguishers. See Section D for guidance on how to avoid nitrate fires. Nitrate can also suffer from the standard deterioration problems of film, such as mold, insect infestations, and vermin infestations, all of which pose additional health hazards. See *Museum Handbook***,** Part II, Appendix R: Curatorial Care of Photographic Collections.

- ***Structural safety problems*****:** As well as being toxic, nitrate fires are known for their intensity and explosive force. Nitrate burns at a combustion rate 15 times greater than that of wood. While burning, nitrate produces toxic and flammable gases—including carbon monoxide and nitrogen peroxide.

  Just five pounds of nitrate (1 reel of motion picture film or 125 negatives larger than 4" x 5" in size) can release over 25 cubic feet of carbon monoxide. These gases are produced at such a rate that they place tremendous pressures on building structures, frequently leading to structural collapse. Nitrate fires usually burn until all fuel is consumed, often accompanied by explosions.

- ***Collection problems*****:** As it deteriorates, nitrate gives off gases that deteriorate other materials, such as paper, leather, fabric, and wood, as well as stone and some metals. The nitric acid created as the result of nitrate deterioration corrodes metal, makes gelatin binders (part of the film image-bearing emulsion) sticky, and fades silver images. Even when in refrigerators or freezers, nitrate should not be housed in general museum or archival storage areas, work spaces, or general office spaces for more than five years) as some fumes are still given off. Nitrate is a threat to the survival of collections housed in the same or nearby buildings. See Sections C.11 and C.12 for guidance on how to house and store nitrate.

6. *What values do nitrate films have for parks?*

Nitrate negatives and motion picture film forms the largest portion of the visual record of the early 20^{th} century. This material has value for a wide variety of purposes, including:

- ***Informational value*:** Nitrate film provides meaningful data and information essential for tracking how parks have changed over time including:

  – activities and events

  – archeological sites

  – buildings and restoration of structures

  – geology

  – historic landscapes and vegetation

  – human impact on ecosystems and fauna

  Nitrate captures the ephemeral, transforming it into a record that can be interpreted, evaluated, utilized as data, and transformed into information and knowledge. Don't lose this information through neglect or disposition. High quality copies can have almost as much informational value as original nitrate. If you have a high quality copy, such as an interpositive copy or a duplicate negative in good condition, you don't have to keep the original negative if it has only informational value.

- ***Artifactual value*:** Materials that are rare, interesting, or outstanding examples of photography or filmmaking have artifactual value. Some nitrate negatives, for example, such as those by Ansel Adams, Lewis Hine, or Carleton Eugene Watkins, are important artifacts in their own right because of their excellence as visual objects.

  Nitrate with high artifactual value will generally have some of the following characteristics:

  – fine composition

  – sharp focus/resolution (unless purposefully impressionistic)

  – good tonal values

  – excellent depth of field (clear focus and image depth in both foreground and background areas)

  – lack of obvious blemishes such as smudges and dust spots

  – representation of the subject matter in a visually arresting, interesting, or surprising way

  – good contrast (clear bright highlights and deep dark shadow areas)

– good range of clear details, even in the dark shadow and bright highlight areas

These high artifactual value nitrate materials must be preserved as major assets until they become so deteriorated that they have lost their functionality and become a threat to other materials. Poorly composed, unfocused, and muddy images would not qualify as having high artifactual value. Generally speaking, high quality copies **don't** capture all the artifactual value of an original photograph. Copy and keep undeteriorated original nitrate that has high artifactual value.

- ***Evidential value*:** Some nitrate negatives serve as either legal or historical proof of an activity, event, occupation, or action, such as law enforcement footage of an illegal activity. The state and federal laws have specific requirements for how evidential materials must be maintained prior to a court case. Such legal requirements might include:

  – an unmanipulated image that has not been dodged, burned, retouched, tinted, or airbrushed, either in the darkroom or afterwards

  – documentation on when, where, how, why, and by whom the image was taken and what it documents

  – a record of a continuous chain of custody by the creator (photographer or his or her employer)

  This evidential nitrate should be kept for its value as legal and historical evidence, although while still active, it is unlikely to be found in museum collections. Legal records may eventually become unnecessary; however, **historical proof is always necessary**. Nitrate film that serves as historical or legal proof must be copied with particular care to ensure that it doesn't lose its usefulness as evidence. You may need to consult with a lawyer or historian before disposing of these legal or historically evidential materials, even after copying. In some cases you may be bound to maintain the original in perpetuity, or at least until it is deteriorated beyond stage 3. See Section B.13 for a description of the stages of deterioration. Copy and keep this original nitrate film. Consult your solicitor for guidance on preserving the evidential value of the original in your copy.

- ***Associational value*:** Some nitrate has importance for its relationship to a notable individual, group, event, place, or activity, such as the images taken by or of presidential family members, famous authors, famous generals, or other notables. Associations might include:

  – an individual or group who created, owned, or was shown in the image, such as Franklin D. Roosevelt

  – an activity, such as a parade, staff-training, or a celebration

  – a movement, such as Suffrage, Emancipation, or Impressionism

  – a geographical locale, such as a particular park site

– an era or event documented, such as the Spanish-American War or Inaugural Day

Generally speaking, associations are more powerful for original materials than with copies. Maintaining the original nitrate will maintain that direct link to the associated individual or group. Copy and keep undeteriorated original nitrate with high associational value.

- ***Administrative value*:** Some nitrate is essential for the day-to-day operation of the parks. This includes nitrate film that documents museum collections; nitrate film used as resource materials for park publications; and nitrate film that serves as documentation of land boundaries, flooding, or forest fire damage. Generally speaking, these materials eventually become part of the park museum collections because of their informational content, if, for example, they contain baseline data on ecosystems. These materials, once copied, inspected, deteriorated, and deaccessioned may be disposed of as NPS hazardous waste according to Environmental Protection Agency (EPA) guidelines. Work with a NPS hazardous waste coordinator. See C.16 and C.17.

B. Identification and Evaluation of Historical Nitrate and Cellulose Ester Film

1. *What transparent flexible film bases have been produced?*

During the late 19th and early 20th century, there were a number of transparent film bases created, including:

- ***Cellulose nitrate (nitrate)*:** Described in Section A.1.

- ***Cellulose ester (acetate) family of safety film bases*:** The cellulose ester family of film bases is usually referred to as triacetate, diacetate, or acetate or is simply called safety film. Though developed to be permanent film bases, unfortunately these films were no more stable than nitrate. Their maximum life expectancy (LE) is 100 years at an average room temperature of 70°F. The major difference between the nitrate and cellulose ester family of film bases is that the cellulose ester films are **not** as flammable. Because of the presence of acidic decomposition byproducts, these cellulose ester film types should be isolated, reformatted, and placed in cold storage as they deteriorate. **Most 20th century color film (slides and negatives) is cellulose ester, even film and transparencies being produced today.** Manufacturers such as Agfa, Ansco, Defender, DuPont, Hammer, and Kodak have produced or are producing cellulose ester films. See Sections B.2-B.4, and B.6.

  – ***Cellulose acetate (acetate, cellulose acetate propionate, and cellulose acetate butyrate)*:** Developed about 1935, these were the first of the "safety" cellulose film types used to replace nitrate. The major improvement over nitrate was an ignition temperature above 800° F.

– ***Cellulose diacetate (diacetate)*:** This is the second of the safety cellulose film types, used to replace nitrate film and acetate around 1937. Like acetate, diacetate is no longer-lived than nitrate. Diacetate films discolor, shrink, and become progressively more brittle over time. Storage environment, particularly temperature and humidity, greatly affects the life of this film. Cellulose diacetate began to be replaced by triacetate in 1948.

– ***Cellulose triacetate (triacetate)*:** This is the last of the cellulose ester films that replaced nitrate around the 1950s. It was first available in 1948 as motion picture film and commonly in use by 1949. As early as 1960, reports began to filter in that cellulose triacetate film was not permanent when stored under warm and humid conditions.

- ***Polyester (polyethylene terephthalate)*:** This refers to a clear neutral plastic film used for film bases since the 1950s. Polyester is a long-lived and durable film base. Films marked “Estar” or “Cronar” are polyester. Manufacturers such as Agfa, Ansco, Dupont, and Kodak produce or have produced polyester films. Polyester is not particularly flammable, does **not** give off dangerous gases, and has a maximum life expectancy (LE) of 500 years.

2. *Does cellulose ester film deteriorate?*

Yes. All flexible films in use before 1950 deteriorate. As cellulose ester films age, deterioration lowers the pH of the cellulose ester’s emulsions (image-bearing layer), causing fading and film-base deterioration. Like nitrate, these films become brittle as they age. Cellulose ester film may develop crystals or bubbles on the emulsion surface of the images.

The classic cellulose ester deterioration patterns are “channeling,” in which the film image layer (emulsion) forms raised blisters and tunnels on the film base and “vinegar syndrome,” described in Section B.3 below. Ultimately, the only effective preservation solutions are reformatting and inspection of the original, followed by cold storage of any undeteriorated originals of continuing value. For more guidance and a rating system for comparing the various types of value, use, and risk, see *Conserve O Gram* (*COG*) 19/10, “Reformatting for Preservation and Access: Prioritizing Materials for Duplication.”

3. *What is the vinegar syndrome?*

As the cellulose ester films (acetate, diacetate, and triacetate) deteriorate, they chemically decompose, producing acetic acid. Acetic acid is the cause of the well-known “vinegar” smell frequently noted around collections of acetate, diacetate, and triacetate. Like nitrate, the decomposition is autocatalytic, meaning that the presence of acidic decomposition byproducts near the original film will speed further decomposition. Using sealed or closed containers hastens this deterioration process by maintaining deterioration byproducts and acetic acid gases next to the film. Like nitrate films, cellulose ester films should be isolated for cold storage. Handle cellulose ester film carefully, as acidic gas byproduct build-up near the film can also be a health hazard.

4. *What does deteriorated cellulose acetate, diacetate, and triacetate film look like?*

Most cellulose ester film types deteriorate in the following characteristic ways:

- ***slight film curl*** (***Note*****:** This is also exhibited by nitrate from the 1889-1903 era)
- ***vinegar-like or acetic acid smell***, which grows stronger as the film deteriorates
- ***film shrinkage***, which can change the film's dimensions
- ***film embrittlement,*** although it doesn't turn amber-colored like nitrate
- ***some warping and planar distortion***, so that the film is no longer flat, but instead has raised areas
- ***bubbles*** in the film emulsion
- ***channels of raised film emulsion*** on the film surface (as the film emulsion separates or lifts from the film base it produces channels, tunnels, and large blister-like features)
- ***silvering-out*** or metallic mirroring or image tarnishing that begins to occur in the densest image areas

  Note**:** Only nitrate has rainbow effects that appear in the darkest and most silvered-out areas of the image. Acetate, diacetate, and triacetate films lose image detail and look dark and reflective when they silver-out; they don't have rainbow-like-patterns.

5. *How do I identify nitrate materials?*

There are several ways to identify nitrate materials, including:

- ***By date of manufacture*****:** Table 1 in Section A.4 provides a review of the dates during which various types and format of film were most commonly used. Most film negatives and motion picture film made in the United States before 1951 are suspect as being potentially nitrate. Additionally some negatives and films made in France during World War II were nitrate.
- ***By internal evidence*****:** Internal evidence is the best way to identify nitrate. There are several common types of internal evidence, including:
  - ***Edge markings*****:** Edge markings or edge prints are actual words on the borders of film that indicate the film name or type. Some manufacturers edge-marked their nitrate film with the word "nitrate," while they marked other film with specific brand names or types of nitrate film, such as "Eastman Nitrate Film." **If** you are dealing with an original negative, you can depend upon the "nitrate" edge marking. ***Note*****:** The marking "safety film" indicates that the film is cellulose ester (acetate, diacetate, or triacetate), while films marked "Estar" and "Cronar" are polyester.

Occasionally, when copying nitrate film to a safety base the nitrate edge markings also were copied. These copies of nitrate on safety base would have both "nitrate" and "safety" edge markings, thus alerting you to their "safety" status. So, the presence of the word "nitrate" as an edge marking is **not** conclusive proof that the material is nitrate if you are dealing with a copy image. Look for V-shaped notch codes (punches taken out of an image border in a particular configuration to indicate the film type to photographers working in a darkroom) in addition to the word "nitrate" for more conclusive proof that the image is nitrate (see notch codes below). Your best use of edge markings is to look for the word "safety." Assume that pre-1950 film or negatives not marked with the word "safety" are nitrate. Also assume that unmarked film produced prior to 1950 is nitrate, until you can test it.

> ***Flexible film-based negatives (not glass, paper, or metal based negatives) and motion picture film produced between 1890-1950, which don't have the words "safety film" marked on them, generally are nitrate. Use this distinction as one easy way to identify nitrate.***

– ***Notch codes*****:** Notch codes are small punches taken out of the border of nitrate, developed to help photographers identify the film type in the dark room. These codes varied over time by manufacturer, process, and format of film. Kodak "V" notch codes, used in combinations of up to three notches, designated that the film was nitrate. When the earliest safety film appeared, the outermost notch became a rectangular "U." After 1949, Kodak reused the old "V" notch codes for safety film. Notch codes provide uncertain guidance and are best used in conjunction with other internal evidence.

– ***Odor*****:** Nitrate film has a pungent nitric acid smell as it deteriorates and may have a camphor-like odor when it burns. These odors should not be confused with the vinegar-like acetic acid smell of deteriorating acetate, diacetate, and triacetate safety film.

– ***Yellowish-brown base color*****:** As it deteriorates, nitrate film changes in color from clear and transparent to a distinctive dark amber tone. To determine if the base has this tone, look along the border or edge of the film where there is no emulsion or cut a small chip from the edge of the film and place the film chip in water. After about 15 minutes, when the emulsion has softened, scrape it to see if the film is amber in color. If it is, the film is probably nitrate.

– ***Base brittleness*****:** Deteriorated nitrate is very brittle. You may cut a tiny chip off the border of a piece of nitrate film and try bending it. Compare the film's resilience to that of a piece of contemporary film by flexing it gently. Nitrate will be significantly more brittle.

– ***Emulsion stickiness*****:** Check the image's emulsion border for stickiness. Emulsions on nitrate that has reached stage 2 of deterioration or higher may be sticky or softened. (See B.13 for a review of nitrate deterioration stages.)

– ***Emulsion mirroring or silvering out*:** Both nitrate and acetate film turn mirror-like or look like tarnished silver—usually in the densest image areas. However, in nitrate the mirroring may appear as a black rainbow, while in acetate there is no rainbow-effect.

– ***Emulsion cockling and buckling*:** As it deteriorates, nitrate shrinks. This shrinkage causes the negative emulsion to buckle and lift-off the cellulose nitrate base. Early safety film (acetate, diacetate, and triacetate) also has an emulsion shrinkage problem that causes the emulsion to separate from the base and form long web-like channels. Channelized film, in which the emulsion lifts off the base to form raised honeycomb-like cells or tunnels, is **always** cellulose ester.

– ***Film gauge***: Though motion picture film has come in a wide variety of gauges, nitrate was not available in all of them:

standard 8mm (never made in nitrate)
super 8mm (never made in nitrate)
16mm (never made in nitrate)
35mm (the most common nitrate gauge)
70mm (less common nitrate gauge than 35mm)

Use the internal evidence indicators above with care, as they may be inconclusive. You may need to test the material to determine if it is nitrate

6. *How do I determine whether film is nitrate, cellulose ester (acetate, diacetate, triacetate) or polyester?*

You can use any of four tests to determine the composition of photographic negatives, transparencies, or motion picture film in your collection:

- ***The polarization test*** identifies polyester film.
- ***The burn test*** identifies nitrate film.
- ***The float test*** identifies all film types.
- ***The diphenylamine test*** identifies nitrate film.

Before using these tests, attempt to identify the nitrate by one of the techniques described in Section B.4 above. Or, use the polarization test (see Section B.7) in conjunction with the techniques described in B.4. While each of the four film tests has particular advantages and disadvantages as described below, **only the polarization test is non-destructive.** Therefore, the polarization test is the preferred test for use with NPS museum collections. Don’t try to undertake the destructive tests (burn test, float test, or diphenylamine test) without training and appropriate facilities, such as fume hoods or an acid/organic vapor cartridge breathing apparatus that has been fitted to the user.

7. *How do I use the polarization test?*

The polarization tests can help you determine if film is made out of polyester. Place the film to be tested between two photographic polarizing filters or two pairs of polarized sunglasses. Twist or “cross” the filters or glasses so that they allow light to pass through them. Project a strong light through the pair of “crossed” polarized filters (or polarized sunglasses) and film. If the film is polyester-based, the shimmering full spectrum of rainbow-like patches will appear on the film. If the film is one of the cellulose esters or nitrate, you will simply see dimmed light, but no rainbows. As the only non-consumptive film test, **the polarization test is preferred over the other testing options.**

8. *How do I use the burn test?*

You can distinguish nitrate from safety film through the use of the burn test (a consumptive test). Cut a small snippet of film from the border (not the image area) of a negative or motion picture film. **Use a fume hood if one is available or an acid/organic vapor cartridge breathing apparatus that has been fitted to the user.** If you have no fume hood or apparatus, go outside of the building, far from any venting nitrate fumes, gasoline, or other flammable materials. Hold the film carefully by the corner using a hemostat or pair of long-handled tweezers.

Light the film snippet using a match.

- ***Nitrate film*** will burn brightly and consistently with an intense white-to-yellow flame. Fire should consume the nitrate snippet completely. Some nitrate film will have a camphor-like odor as it burns, although formulations varied during creation.

- ***Safety film*** will smolder and go out when the match is removed, leaving a melting or dripping mess behind and an acetic acid, vinegar-like odor.

You will need experience before you can use this test as a conclusive measure. On your first few attempts, work with film that has already been identified in order to experience the testing characteristics of both film types.

9. *How do I use the float test?*

Another way to distinguish nitrate from safety film is the float or trichloroethylene test (a consumptive test). Trichloroethylene is a dangerous volatile chemical and a known carcinogen, so avoid touching the trichloro-ethylene or breathing in the chemical's vapors**. When working with trichloroethylene use a fume hood and wear neoprene gloves** or work outdoors using an acid/organic vapor rated cartridge in a rated breathing apparatus fitted to the user and neoprene gloves. Never carry this open chemical through your storage, work, or reference areas.

Take a 6 mm x 6 mm chip (snip) of film to be identified from a film border. **Be sure to cut only the non-image area**. Place the film chip in a beaker or test tube of trichloroethylene. Place a lid on the beaker and shake it or press the film chip down into the fluid until it is thoroughly wet. The film will either float, sink to the middle of the beaker, or sink to the bottom of the beaker.

- Cellulose ester (cellulose acetate, diacetate, and triacetate) safety films float at the top of the beaker.

- Polyester film floats at the middle of the beaker.

- Nitrate film sinks to the bottom of the beaker.

After the test you must work with your hazardous waste coordinator to store and/or dispose of the trichloroethylene and the test strips according to EPA guidelines.

10. *How do I use the diphenylamine test?*

Perform the diphenylamine test (a consumptive test) very carefully as the solution contains about 90% sulfuric acid. Obtain a solution of diphenylamine and sulfuric acid, as described in the Canadian Conservation Institute's "The diphenylamine spot test for cellulose nitrate in museum objects," *CCI Notes* (17/2). Place a small film chip (from a border or non-image area) on a microscope slide and add a drop of the prepared diphenylamine solution. After 60 seconds, if the film is nitrate, it will turn a deep blue. Both cellulose ester and polyester films will either remain clear or turn a very pale blue, not a vibrant, deep blue.

To confirm the test result, apply two additional drops of the solution to the film chip and wait another minute for the film to turn deep blue. Conduct this test under a fume hood or outdoors wearing an acid/organic-vapor rated cartridge in a rated breathing apparatus fitted to the user, as **the sulfuric acid may irritate your mucous membranes.**

11. *What determines the speed of nitrate deterioration?*

Nitrate begins self-destruction at the moment of creation. **Nitrate film self-destructs at an unpredictable rate.** The only way to estimate when nitrate will be unusable is to have a conservator conduct the consumptive tests listed in Section B.14 on each individual sheet or roll of film—hardly a practical alternative. Several factors cause chemical or mechanical deterioration of nitrate, including:

- ***Manufacturing and processing history*:** During the early days of mass photographic processing each batch of photographic film had a slightly different composition. Factors affecting the life of the image include:

  – the nitrate composition

  – the nitrate thickness

  – the emulsion quality

  Residual processing chemicals, such as sodium thiosulfate and silver complexes, affect the life of the image but seem to have little to do with the actual life of the nitrate base. You may test for residual processing chemicals (particularly thiosulphate) in a variety of ways, ranging from using test strips to hiring a lab to conduct chemical tests, such as the methylene blue test. See Sections B.15 and C.15.

- ***Storage and housing environment*:** The storage and housing environment involves a wide range of factors that may affect the rate of deterioration, including:

  – air contamination and pollution

  – housing envelopes, sleeves, folders, and boxes

  – insects

  – light

  – mold

– relative humidity

– rodents

– storage equipment

– temperature

– ventilation

– water

See Sections C.11 and C.12 for information on how to house and acclimatize nitrate and cellulose ester films.

- ***Handling*:** Abusive handling can cause scratches and abrasion, while direct hand contact can deposit oils, which ultimately lead to emulsion staining. Avoid using nitrate frequently for duplication purposes as this places great stress on a negative. Never project nitrate. Reformat frequently used materials to provide access, duplication, and archival preservation master copies. See *COG* 19/10, "Reformatting for Preservation and Access: Prioritizing Materials for Duplication," for further help in determining what nitrate to reformat first.

12. *Is nitrate deterioration predictable?*

No. Although nitrate does go through five sequential stages of deterioration, without sophisticated chemical testing by a professional, it is impossible to predict how long the negative will exist in each stage. Film that has lasted for 60 years at stage 1 (relatively good condition) may go through stages 2-3 in only a few months, depending upon how the nitrate is stored and handled. Cold storage and regular inspection of nitrate is essential if collections are to be preserved.

13. *What are the stages of nitrate deterioration?*

There are five stages of nitrate deterioration.

- ***Stage 1*:** Film base discolors to a light amber tone.

  – Image fades.

  – A faint acidic or nitric acid smell may be detectable.

  – Image may stain, totally or in part, or exhibit "mirroring," where it becomes dark and reflective.

  – A black, rainbow-like iridescence may be visible, not unlike an oil slick.

  ***(Note*:** Even the best preserved nitrate is now at least in stage 1 deterioration.)

- ***Stage 2*:**

  – Emulsion may soften.

- Negative may become sticky, attaching itself to paper sleeves or other film.
- Film base may become brittle.
- Film base amber color may deepen.
- A slightly stronger acidic or nitric acid smell may be apparent.

Note**:** In many cases stage 2 is the last stage at which nitrate can be copied or reformatted.

- ***Stage 3*****:**
  - Emulsion may begin to separate from the base.
  - Nitric gas bubbles appear between the film base and the emulsion (image-bearing layer).
  - Film base is very brittle and deep amber in color.
  - Significant "mirroring out" or mirror-like, reflective black staining is apparent, often with a rainbow-like appearance.
  - Nitric acid smell is strong.
- ***Stage 4*****:**
  - Emulsion begins to flow.
  - Sticky froth appears on the negatives.
  - Film sticks to nearby housing or negatives.
  - Image surface is easily damaged.
  - Nitric acid smell intensifies.

  (Note**:** Film in this deterioration stage should be disposed of as hazardous waste. See C.16 and C.17.)
- ***Stage 5*****:** ***(Note*****:** Film in this deterioration stage should be disposed of as hazardous waste. See C.16 and C.17.)
  - Emulsion turns into an acrid brownish or tannish powder that is highly acidic.
  - Film shatters or breaks easily, as the nitrate base is **very** brittle.
  - Film can self-combust if stored near high temperatures or sparks. ***Note*****:** This is a rare condition in still negatives except for those of the largest sizes housed without sleeves.

14. *What chemical tests can be used to predict whether nitrate life has been exceeded?*

Two chemical tests can indicate whether nitrate should be immediately destroyed or not. These tests are:

- the Alizarin red heat test
- the Micro-crucible test

Don't attempt to do these tests yourself without a sophisticated chemical laboratory and excellent training. Send film to be tested to an outside chemical laboratory, which will provide you with the results and a recommended date for retesting.

15. *What tests can be used to predict the life of cellulose ester films?*

The Image Permanence Institute developed A-D test strips® for use in determining the level of cellulose ester film deterioration. Similar to pH test materials, the strips indicate the level of degradation in individual films. Use the strips to determine if storage conditions are adequate and to help you set reformatting priorities. The strips are available from the Image Permanence Institute (one package contains 250 detector strips about 1 1/2" x 3/8", a color-reference pencil, and instructions), Rochester Institute of Technology, 70 Lomb Memorial Drive, Rochester, NY 14623-5604; Tel: 716-475-5199; Fax: 716-475-7230.

Place an individual strip in the container of the film to be tested (within a motion picture can, bag, box, sleeve, or cabinet). ***Note*:** Wear neoprene gloves to do this if you are working with deteriorated film. You may wear latex or cotton gloves if the film is undeteriorated. After exposure, the test strip color is compared to the reference pencil, which is printed with four bands of color, numbered from 0 to 3. The four bands of color correspond to the four levels of acidity. The reading indicates the extent of deterioration. ***Note*:** A-D test strips® are not useful indicators for polyester film deterioration. Some organizations, including the National Archives, however, are using them for indicating deterioration in **both** cellulose ester films (acetate, diacetate, and triacetate) **and** nitrate.

16. *How do I ensure the long life of cellulose ester films?*

Long life of cellulose ester film depends upon cool temperature, controlled relative humidity, a well-ventilated storage space, and good housing, as well as appropriate handling. The film age and type (acetate, diacetate, or triacetate) doesn't determine the speed of deterioration, though the original manufacturing, processing, storage, and handling history does affect the film life. Lowering the temperature to 2°F (-18°C) can extend by 200 times the life expectancy (LE) of film stored at 80°F. At 70°F the LE is approximately 100 years from the date of manufacture. Lowering relative humidity to 20% from 50% or higher can triple or quadruple the film LE.

The ***IPI Storage Guide for Acetate Film*** created by the University of Rochester's Image Permanence Institute can be used to predict life of acetate film at specific temperatures and relative humidities. Separate all nitrate and cellulose ester films from each other, from other film types, and from all deteriorated films of any kind. House these films in cold storage within the cold storage system configuration described in Sections C.11 and C.12. Place cellulose ester films in a cool, dry, well-ventilated space (ideally 0°F, 30% RH) housed separately from all other materials and office spaces to slow deterioration byproduct build-up. Use copies for reference and access.

Access the originals only when a new set of interpositives and copy negatives must be produced. If cold storage is not possible, house the materials off-site in cold storage. See Sections C.3, C.11, and C.12 for further guidance.

17. *Where can I get help on these issues of nitrate and cellulose ester identification and deterioration analysis?*

You can get help from SO and regional staff, Harpers Ferry Center (HFC) Division of Conservation staff, and from colleagues at your state university and state and local archives and libraries, as well as from contract archivists and curators.

C. Management of Nitrate and Cellulose Ester Films

1. *Do I have to keep nitrate film?*

Yes. You must keep nitrate film at stages 1 and 2 of deterioration (Section B.13) that has high artifactual, evidential, and/or associational value. Keep any nitrate film, regardless of value, if it has not yet deteriorated to stage 3 or beyond and has not been reproduced, inspected, and the reproduction approved. If you are uncertain about the value of film, keep it until an archivist can determine whether it has high artifactual, associational, or evidential value.

You may dispose of:

- ***film with little or no artifactual, associational, or evidential value*** as long as it has been reformatted and the copies have passed inspection

- ***film of informational or administrative value*** after high quality copies have been made that clearly reproduce **all** the information in the original and have passed inspection (If you are uncertain if all the information is conveyed in the copy, keep the original until an expert can check the film and copies to determine if the copies pass inspection.)

- ***all film in stages 3-5 of deterioration*** after you deaccession it, regardless of its original value

Work with your hazardous materials coordinator to dispose of badly deteriorated nitrate as hazardous materials according to the Environmental Protection Agency (EPA) Waste Codes and guidance. Don't attempt to do this by yourself. If your park has no hazardous materials coordinator, talk to your SO or regional curator or work with your local fire department to arrange a multi-park or regional disposition effort.

> ***The only nitrate you must keep permanently after producing high quality copies that have been inspected is nitrate in deterioration stages 1 and 2 that has high artifactual or associational value and material of continuing evidential value. If you are inexperienced in judging value, keep all stage 1 and 2 nitrate film and make immediate arrangements for an experienced archival appraiser to determine whether to keep the originals.***

See *COG* 14/8, "Caring for Cellulose Nitrate Film"; 19/10, "Reformatting for Preservation and Access: Prioritizing Materials for Duplication"; 19/12, "Contracting for Reformatting of Photographs"; and 19/13, "Preservation Reformatting: Inspection of Copy Photographs"; and Sections A.6, B.6, B.11, B.13, and B.14 for further guidance. Also see *Museum Handbook*, Part II (*MH-II*)**,** Chapter 6: Deaccessioning, for guidance.

2. *Do I have to keep other deteriorating film types, such as cellulose acetate, diacetate, and triacetate?*

No. Deal with other deteriorating film types as you would nitrate, although cellulose ester films don't pose such major safety hazards, as they are **not** a fire risk. Some individuals are sensitive to the acetic acid given off by the cellulose ester films. If health or safety issues become a factor, such as those caused by badly deteriorated collections, mold, insect or vermin infestation, or a chemical spill, follow the nitrate guidance.

Keep all original materials of high artifactual, associational, and evidential value in cold storage. Reformat and inspect your deteriorating items **before** they can no longer be used. After deaccessioning contaminated items, work with a NPS hazardous waste coordinator to dispose of them according to EPA guidelines. See Sections A.6, C.14, C.16, and C.17.

3. *What special storage requirements must my facility meet?*

Don't store nitrate, acetate, diacetate, or triacetate in:

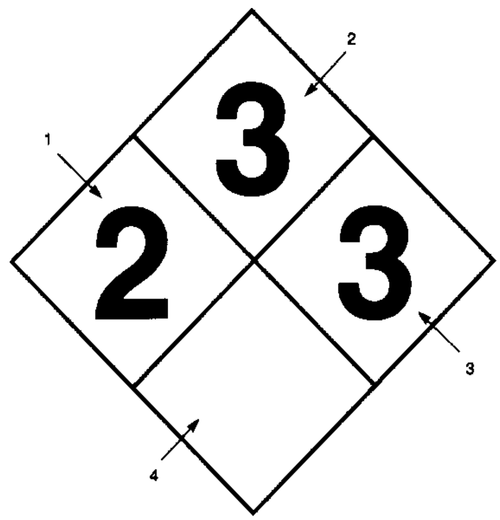
- office spaces
- attics
- general museum storage spaces
- historic buildings
- near windows or doors
- near light or heat sources
- in spaces with poor ventilation
- in spaces with no air conditioning
- in spaces without deluge sprinkler systems

For short-term storage of five years or less, house the collections as described in Section C.12, then place them in frost-free food freezers. This is **not** a recommended long-term solution because the deterioration byproducts may eventually build up in the freezer or refrigerator, causing health and safety hazards.

For long-term storage of more than five years, apply the National Fire Protection Association (NFPA) standards, particularly *NFPA 40, Storage and Handling of Cellulose Nitrate Motion Picture Film,* to all cellulose ester and nitrate film formats. No separate NFPA standards currently exist for still photographic negatives. Parks should not plan to store nitrate film for the long term on park grounds.

NFPA 40 is a rigorous standard that will result in very high-quality cold storage vaults with excellent venting, environmental controls, and fire resistance. However, the cost of applying this standard exceeds $30 a square foot. NFPA 40 standards for vaults include stringent requirements for ventilation, refrigeration, heating, air conditioning, fire resistance, fire suppression, and temperature readouts. The vault will also require constant monitoring, much electricity, and scrupulous management to ensure environmental stability. **Parks wishing to build a nitrate storage vault should not do so in or near historic structures or in the same building as visitor centers, staff offices, or collections.**

Label all nitrate storage areas and freezer vaults with the National Fire Protection Association (NFPA) Hazard Warning Symbol for nitrate shown in Figure M.1 below. Make sure that you notify all local fire stations of the presence and location of nitrate accumulations in your park. ***Note*****:** If you are planning to store only cellulose ester films (which like nitrate should be housed in separate packaging and placed in containers separate from that of nitrate or polyester films), you simply need temperature, humidity, ventilation, and lighting control. See Sections C.11 and C.12 and *COG* 14/4, "Caring for Photographs: General Guidelines."



1 – Health Hazard (BLUE)
2 – Flammability Hazard (RED)
3 – Reactivity Hazard (YELLOW)
4 – Special Hazard (WHITE)

Figure M.1. National Fire Protection Agency Hazard Warning Sign for Cellulose Nitrate Film

4. *What other options do I have if I don't want to store film in my park?*

Consider the following options:

- ***Rent a cold storage vault*****:** Hire a cold storage vault outside of the park, such as the Bowers or Iron Mountain facilities in Pennsylvania or Bonded Film Storage in Fort Leigh, New Jersey (201-944-3700) and W.R.S. in Pittsburgh, Pennsylvania (412-937-7700). Although these facilities don't meet the optimum requirements, they do offer improvement over standard office and museum storage.

  Note**:** Henry Wilhelm states in *The Permanence and Care of Color Photographs,* on page 342, "At the time this book went to press in late 1992 . . . there was no commercially available humidity-controlled, low-temperature (0°F [-18°C] and 25% to 35% RH) film storage rental space available anywhere in the world." For more current information on cold storage suppliers, equipment, enclosures, and facilities that rent cold storage space, see the list in *Tools of the Trade***.**

- ***Use a NPS facility*****:** Move your film to a NPS storage and collections management facility with monitored cold storage, such as the Western Archeological and Conservation Center in Tucson or the San Francisco Maritime Museum.

- ***Cooperatively share a vault*****:** Share a cold storage vault with a state, federal, or local agency, such as your state archives or library or a local university.

- ***Sublet cold storage space*****:** Sublet cold storage space in a vault owned by another organization.

- ***Ask for help*****:** Request cold storage space from the National Archives and Records Administration (NARA) or your Regional Archives Center, also operated by NARA.

5. *How should I manage nitrate that I must keep in the park on a short- or long-term basis?*

When managing nitrate, do the following:

- ***Know the law,*** particularly EPA, state, and local ordinances about the keeping and destruction of nitrate. Read the various standards and recommendations in the bibliography.

- ***Talk to your local fire department and safety-related park staff.*** Ensure that they know where the nitrate is located in the park and the quantities and condition of the nitrate. Label the nitrate storage areas clearly with the NFPA Hazard Warning Symbol for nitrate to facilitate effective fire fighting. See Figure M.1.

- ***Isolate and label the materials*** in a safe, humidity-controlled venting cold storage facility (0°F [-18°C] and 30% RH) far from museum storage, work, exhibit, and office areas.

  – Your best option is to use separate storage packets (nitrate separated from cellulose ester) with the nitrate packets housed in a separate environmentally stable vented cold storage chamber (vault room) by itself that meets NFPA standards.

  – Your second best option is to use separate storage packets (nitrate separated from cellulose ester) in environmentally stable cold storage with the nitrate and cellulose ester in the same cold storage vault. This option is perfectly acceptable as long as the temperature and humidity are both controlled (0°F (-18°C) or cooler and 30% RH), there is some venting, and a back-up power source is available.

  – Your third option is to use separate storage packets (nitrate separated from cellulose ester) protected by Molecular Sieves (dispersed molecular traps that absorb gaseous residues) with the temperature and humidity at least somewhat controlled in food freezer-type cold storage as described in Sections C.11 and C.12. Deteriorating materials should be duplicated and removed ASAP. This option is acceptable as long as the temperature and humidity are controlled and there is a back-up power source.

– Your fourth and least desirable option is to use separate storage packets (nitrate separated from cellulose ester) protected by Molecular Sieve materials in standard museum storage. Use this only for short periods as film materials are prepared for duplication prior to cold storage.

Standard food freezers or refrigerators, whether frost-free or not, do NOT meet fire code standards because they are not vented, don't stop the build-up of toxic gases, and don't meet the need for a powerful deluge-type, wet-pipe fire extinguishing system. Such storage is NOT acceptable for permanent nitrate storage.

- ***Duplicate materials*** following American National Standards Institute standards and archival best practices. (See *COG* 19/11, "Preservation Reformatting: Selecting a Copy Technology," and 19/12, "Contracting for Reformatting of Photographs.") ***Note*:** Digital copies are **not** preservation copies. See Section C.14.

- ***Inspect duplicates*** of the original materials carefully for accuracy, completeness, and technical quality. (See *COG* 19/13, "Preservation Reformatting: Inspection of Copy Photographs.") Make new copies if any don't meet standards and reinspect. Repeat if necessary until high quality copies are achieved. See Section C.15.

- ***Evaluate the remaining nitrate's condition.*** If it is stage 3 or worse, work with a NPS hazardous waste coordinator to dispose of it according to EPA guidelines. See Section B.13 for a review of the stages. Keep materials with high artifactual, associational, and evidential value. (See Section A.6 and *COG* 19/10, "Reformatting for Preservation and Access: Prioritizing Materials for Duplication," for guidance.)

- ***Deaccession and dispose of film*** deteriorated to stage 3 or beyond, film with no relevance to the park's SOCS, and well-copied items with only informational/administrative value. Transfer them to another institution after deaccessioning if they have value or dispose of them. See Sections C.16 and C.17 and *MH-I*, Chapter 6: Deaccessioning, for guidance.

- ***House materials with high artifactual, evidential, and associational values*** in appropriate housing and storage containers in cold storage. See *COG* 14/6, "Caring for Photographs: Special Monochrome Processes," and Sections C.11 and C.12 below.

- ***Manage the cold storage facility*** carefully. Ensure that you have a back-up power source and a power outage alerting system in case of power failure. Inspect the contents every six months (see below). Check the cold storage facility weekly to ensure that there is no power outage or mechanical fault. Never store food or other materials in a film cold storage vault. Maintain monitoring records of the cold storage environment (temperature and RH).

- ***Inspect a different 10% of all retained nitrate, acetate, diacetate, and triacetate every six months*** for deterioration. Check RH indicator strips of materials in cold storage to identify punctured or torn bags requiring replacement and re-drying of their special humidity-controlling enclosures. See Sections C.11 and C.12 for details on how to house materials for cold storage. Replace all punctured bags and re-dry the special boards being used as humidity buffers. Check the contents of punctured bags or bags whose humidity indicators detect humidity greater than 40% RH. Look for blemishes, silvering out, and other deterioration patterns described in Sections B.4 and B.13.

Remove negatives carefully from sleeves and look at them on a light table. To inspect motion picture film, unwind it slowly onto another reel with a smooth even pressure. If you find some seriously deteriorated items, arrange for their **immediate reformatting**, inspection, and disposal. ***Note*:** If more than 70% of the nitrate viewed during inspection is deteriorated, you should then inspect all of the remaining nitrate.

- ***Move the nitrate, acetate, diacetate, and triacetate to a remote cold storage facility if the power in your cold storage facility should go off for more than 48 hours.*** A nearby backup cold storage facility should be listed in your park's disaster and emergency operations plans. See *COG* 14/8, "Caring for Cellulose Nitrate Film."

6. *Should I isolate and handle cellulose acetate, diacetate, and triacetate in the same way?*

Yes. First reformat all acetate, diacetate, and triacetate film of value and inspect the copies. Place the undeteriorated originals that have high artifactual, evidential, and associational value in cold storage to slow deterioration and minimize the deterioration byproduct gases. Don't place these cellulose ester materials in the same cold storage chamber as nitrate unless the chamber is kept well ventilated and very, very cold (0°F [-18°C] or cooler and 30% RH).

House the film as described in C.11 and C.12. Don't place cellulose ester films in work spaces, museum storage, reference spaces, or office areas because they also give off acidic deterioration gas byproducts that may pose health hazards for some individuals. For more guidance, see the *IPI Storage Guide for Acetate Film* in the bibliography.

7. *What should I do when working with nitrate to avoid health hazards?*

First, isolate nitrate far from other collections, research rooms, and staff work and office spaces. When handling nitrate there are a number of routine precautions you should take:

- ***Maintain a log*** of who works with nitrate for health monitoring.
- ***Stop working with nitrate immediately*** if you experience any shortness of breath or eye or skin irritations.
- ***Wear protective clothing,*** including:
  - latex or cotton gloves for undeteriorated film; neoprene gloves for deteriorated film
  - a long-sleeved, washable smock
  - goggles, if working with deteriorated film

– an acid/organic vapor-rated cartridge in a rated breathing apparatus fitted to the user

- ***Wash regularly*** all clothing, gloves, goggles, and work surfaces used for nitrate work; don't wear dirty or reused gloves
- ***Don't wear contact lenses*** when working with nitrate. Gases may build up under your lenses causing eye injury.
- ***Limit your work with nitrate*** to three hours per day.
- ***Position a fan*** so that the airflow blows fumes towards an air outtake valve or open window and away from you.
- ***Never rub your skin, hair, or eyes*** with a nitrate contaminated gloved hand.
- ***Never inhale fumes*** from nitrate or cellulose ester film.
- ***Work in a cool space*** far from any sources of heat, flames, or sparks.

8. *How do I avoid health hazards with cellulose ester films?*

Handle cellulose ester film as you would nitrate. Work only in a well-ventilated room to avoid breathing problems caused by acidic byproducts related to vinegar syndrome. (See Section B.3.) If the room lacks good ventilation, place a fan so it blows on you and position yourself in front of an air outtake register or open window, so the fumes are sucked away from you. Wear neoprene gloves if the film is deteriorated, or cotton or latex gloves if the film is in good condition. If the film is deteriorated and the ventilation is poor or you are sensitive to cellulose ester film, wear an acid/organic vapor-rated cartridge in a rated breathing apparatus fitted to the user. Don't wear contact lenses around cellulose ester film.

9. *How should I mark nitrate and cellulose ester films?*

Individual copy negatives and interpositives may be marked on their reverse edge (on the back in an area that is the reverse of the border of the image) with a photographic marking pen that has neutral pH carbon ink and has passed the Photographic Activity Test (PAT). The PAT is described in *COG* 14/2, "Storage Enclosures for Photographic Prints and Negatives." Consider using the Pigma Ink pen by Light Impressions for marking.

Remove all images before writing on an envelope or sleeve. Let image labeling dry thoroughly before re-inserting images in sleeves or envelopes. Generally mark only minimal information (the negative number or catalog number) in very small characters on the non-emulsion side in the non-image area. Never mark in the actual image area or on the reverse of the image. Label envelopes and sleeves on the seamed side, or if using a four-fold sleeve, label on the top of the fold area.

10. *What common factors affect the life expectancy of nitrate and cellulose ester films?*

Of all the factors affecting nitrate life, temperature, relative humidity, ventilation, handling, and housing systems and equipment are perhaps the most significant. Recent studies by Peter Adelstein and others indicate that the nitrate storage environment, particularly temperature and humidity, are crucial to safe handling and long nitrate life. For every 10°F decrease in storage temperature, the film life is almost doubled. Lowering relative humidity to the 40-60% range from the 70-80% range doubles the life of the film. For long-term storage, 20-30% RH is recommended.

11. *What materials and systems should I use to house my nitrate and cellulose ester?*

Use housing that meets the *American National Standards Institute (ANSI) Standard IT 9.2-1991, Photographic Processed Films, Plates, and Papers-Filing Enclosures and Storage Containers***,** that is a high alpha-cellulose clamshell box made of acid-free materials with reinforced seams**.** Select high-alpha cellulose, four-fold paper sleeves that pass the photographic activity test. Transfer the label and caption information onto this folded side, and place the emulsion so it faces the non-fold side. Place the emulsion side of negatives away from the labeled side of the sleeve to avoid label loss if the film deteriorates. If you use a slide-in sleeve, treat the seamed side like a flap so that the emulsion is away from the seam on the unlabeled side. Use buffered sleeves for cellulose nitrate and for black-and-white cellulose ester film, but use unbuffered sleeves for all color film.

For long-term storage, place your rehoused collections in polyethylene bags or polypropylene film cans within drop-front storage boxes within a second layer of polyethylene bag inside a cold storage vault. Use zeolite materials (dispersed molecular traps that absorb gaseous residues) to protect your film from the buildup of acidic gas byproducts that hasten film destruction if the items are:

- particularly precious
- very large format (8" x 10" and larger) or in large quantity (more than 35 pounds)
- unable to be placed immediately in a cold storage vault
- in a vault with poor environmental controls

Zeolite materials include MicroChamber™ packaging or FPC® Molecular Sieve packets. The packets are placed inside each film container. The packaging is used just as acid-free packaging is normally used. Zeolite materials without cold storage don't by themselves provide adequate protection from deterioration. They simply capture gaseous byproducts that speed deterioration; they don't stop deterioration. Don't reuse zeolite or other housing materials or old containers of any sort. If a film can or box is deteriorated, replace it. Zeolite is an excellent storage material, but may be too expensive for many uses.

The use of the double-bag or Safecare®-type housing system (which includes polyethylene bags, humidity conditioned mat board, RH indicator strips, and boxes) for cold storage of film protects it from condensation, mechanical damage, and handling damage. ***Note*****:** All of the materials found in the Safecare® system are currently found in the *Tools of the Trade*.

If you use venting, hazardous-material freezer(s) for long-term housing without zeolite housing or FPC® Molecular Sieve packets, keep nitrate and cellulose ester films in separate packages within the freezer(s) as described here and in C.12. When possible, also house and store deteriorated film separately from non-deteriorated film. Keep film freezers far from office, museum storage, work, or reference spaces (at least not in the same building and not in any historic structure). Ideally, all vaults and freezers should be checked for collection deterioration at least every six months.

The combination of the two systems—zeolites to control outgassing and Safecare®-type storage systems to control condensation, mechanical damage, and handling damage during cold storage—is ideal. This combination provides maximum protection although the cost may be excessive. Cold storage and the Safecare® system of polyethylene bags, board, and humidity indicator alone are an excellent and relatively inexpensive storage option. A third system is the use of heat or pressure seal bags constructed of layers of foil, paper, and plastic. These bags form an excellent moisture barrier but can't be easily reused after opening, nor are they transparent for examining the condition of the film. These sealed, multi-layered bags are also significantly more expensive than the polyethylene bags.

For long-term storage, house each type of material (deteriorated nitrate, undeteriorated nitrate, deteriorated cellulose ester films and undeteriorated cellulose ester films) separately in its own cold-storage package. Never mix deteriorated and undeteriorated materials or cellulose ester and nitrate materials in the same package. When housed in a cold, dry environment (0°F [-18°C], 30% RH), in dark storage, with low-levels of gaseous pollutants, and a good air circulation/ventilation system, nitrate negatives will endure.

Container selection is also important. Using acidic housing, tightly sealed housing, or no housing hastens nitrate destruction by allowing gas buildup in containers or storage spaces. Except when housed in cold storage or with zeolite materials, place nitrate in vented storage in order to allow the nitric oxide gases to escape. Even cold storage rooms should be explosion proof and vented without internal electrical components other than lighting and humidity/temperature gauges. See Section C.3 for information on short- and long-term storage.

12. *How should I prepare my collections for cold storage?*

Don't rehouse materials for cold storage until **immediately** before storing them. Long-term storage at room temperature in sealed containers or plastic envelopes or sleeves may be damaging. If a film can or box is deteriorated, replace the container. Don't reuse old containers. Ideally, select vented polypropylene cans for film. To implement this system place sleeved film (either buffered or zeolite materials) within cold storage kits configured like the Safecare® system, which works as follows:

- ***Step1*:** Condition the film by storing it at 40% RH for several days to limit the possibility that condensation will form within the sealed bags when the bags are placed in the cold storage.

- ***Step 2*:** Rehouse the images in acid-free sleeves or envelopes or in vented polypropylene film cans. ***Note*:** If you have adequate funds, use zeolite sleeves for negatives and place FPC® Molecular Sieve packets in the boxes housing the film or film cans when you have either rapid deterioration or less than optimum environment controls or you have materials of exceptional artifactual value.

- ***Step 3*:** Place the sleeved or canned film within a polyethylene bag with a RH indicator strip, then gently press all the air out of the bag before sealing.

- ***Step 4*:** Oven-dry (200°F for 3-5 minutes) or microwave-dry (full power for 30 seconds, then turn and repeat) a pre-cut mat board; then allow it to cool.

- ***Step 5*****:** Label a 13" x 10" x 1½" drop-front storage box with the collection name, catalog number, "hazardous nitrate," and any other useful information.

- ***Step 6*****:** Place the cool oven-dried mat board in the bottom of the storage box. Don't overfill the box.

- ***Step 7*****:** Check the bag seal to ensure it is tight and complete.

- ***Step 8*****:** Place the bagged film on top of the mat board. Don't place more than one type of film (nitrate, deteriorated cellulose ester, undeteriorated cellulose ester) in a single box.

- ***Step 9*****:** Place a second oven-dried mat board on top of the bag holding the film. Close the box lid.

- ***Step 10*****:** Place the box inside the second polyethylene bag, add the second RH indicator strip, then press all the extra air out and seal it. Check the RH indicator strips every six months or so.

Sealed materials housed in cold storage in this way should be stable for up to 15 years before you must re-dry the mat board and replace the RH indicator strips. When you remove materials from cold storage, allow them three hours to acclimatize before unsealing. Acclimatize the materials by placing them on an open rack for even heat transfer **before opening the bag.** Wipe off any condensation from the outer bag before opening it.

If you rehouse the image in cold storage, oven dry the mat boards again before replacement. Check all polyethylene bags for holes prior to reuse. Replace all bags with poor seals or holes. Don't place packaged materials directly on the floor of the cold storage facility or on closed shelves directly under pipes. Label the freezer with the NFPA Hazard Warning Symbol for nitrate. See Figure M.1. If you use FPC® Molecular Sieve packets, house the film as described above, but use double polyethylene bags to contain the film storage can or negatives

13. *How should I clean dirty films?*

Never try to clean film in stages 3-5 of nitrate deterioration or any film with a sticky, soft, flowing, flaking, or powdering emulsion. If you must clean cellulose ester or nitrate film, don't use water or solvents, but you may use compressed air or brush the film gently with a soft, clean, and wide camels hair brush. If any damage is noted, stop immediately. Wash the brush regularly and allow it to dry thoroughly before resuming work. Ideally, use several brushes, so you won't have to wait for them to dry before resuming cleaning. Generally, clean only for duplication purposes.

14. *How should I reformat my nitrate and cellulose acetate, diacetate, and triacetate?*

Work with a photographic contractor who is a specialist and understands the fire and safety hazards involved in nitrate duplication and has experience copying deteriorating nitrate or cellulose ester film. Ask your state librarian or archivist for local recommendations.

- Work with a NPS or other expert or your regiona/SO curator to select a reformatting technology, prepare your contract, and implement a quality control program.

- Select a contractor who has scanning laser or cathode ray tube cameras, which don't have hot, quartz-iodine light bulbs.

  – Select items to be reformatted based on the park's Scope of Collection Statement and the film's value, use, and risk. See Section A.6.

  – Select a reformatting process.

  – Write the contract. Insist on the use of long-lived film with a polyester film base, small grain, long tonal range, and good resolving power. Cite the processing standards in the contract.

  – Clean the film, if necessary, using a brush and compressed air. See Section C.13 above.

  – Pack the film for shipment.

  – Inspect the returned copies side-by-side against the original on a light table with color balanced bulbs. Visually inspect the film for completeness. See *COG* 19/13, "Preservation Reformatting: Instpection of Copy Photographs."

  – Have a professional test the film density, resolution, and residual thiosulfate of the copy (densitometric tests and methylene blue tests).

  – Reduplicate any images not meeting inspection and testing standards.

  – Reorganize the copy film to match the original order of the original film. See *MH-II***,** Appendix D: Museum Archives and Manuscript Collections, Section J.

  – Label and rehouse the reformatted copies. See Section C.12 above.

  – Store copies as described in *MH-I*, Appendix R: Curatorial Care of Photographic Collections.

  – Analyze the original film's deterioration state. See Sections B.13 and B.15.

  – Rehouse any originals to be kept in appropriate materials, polypropylene bags, and cold storage after acclimatization at 40% RH. See Sections C.11 and C.12.

  – After deaccessioning, work with the park's hazardous materials coordinator to destroy selected deteriorated originals according to EPA standards. See Section C.1 for guidance on what to destroy and Sections C.15, C.16, and C.17 on how to dispose of it.

  – Set up standard operating procedures to limit access to negatives collections except when making new negatives, answering FOIA requests, or meeting other legal requirements, such as subpoenas.

- Be particularly careful to warn all personnel involved in handling, shipping, or caring for nitrate about the need to keep it cool and away from sparks and ignition sources.

- Don't expect to use digital copies effectively as preservation copies unless your park has developed a professional electronic records migration strategy. Such a policy involves systematic retensioning (rewinding and production of a new tape pack) annually or biannually, data refreshing every three to four years, and migration (copying to new format or media) each time the hardware or software changes (at least every five years). When setting up such a migration strategy, you should plan to keep your large digital master file off-line in non-proprietary and uncompressed formats. You will use derivative usage files online rather than your master files.

- Follow the specific guidance in *COG* 14/8, "Caring for Cellulose Nitrate Film"; 14/4, "Caring for Photographs: General Guidelines"; 19/10, "Reformatting for Preservation and Access: Prioritizing Materials for Duplication"; 19/11, "Preservation Reformatting: Selecting a Copy Technology"; 19/12, "Contracting for Reformatting of Photographs"; and 19/13, "Preservation Reformatting: Inspection of Copy Photographs."

15. *How should I inspect reformatted nitrate that has been returned?*

Follow the techniques for visual inspection, and densitometric, resolution, and residual chemistry testing described in *COG* 19/13, "Preservation Reformatting: Inspection of Copy Photographs." Once the copies have been approved, check the original nitrate's deterioration state. If it is at stage 3 or beyond (see Section B.13), deaccession the nitrate and work with the park or region's hazardous materials coordinator to dispose of the film as hazardous waste according to the EPA guidelines. If the film is at stage 1 or 2 of deterioration, and it has high artifactual, evidential, or associational value (see *COG* 19/10, "Prioritizing Material for Reformatting"), then place the collections in appropriate housing and put them in suitable cold storage after acclimatizing them. See Sections C.11 and C.12. Otherwise, deaccession and dispose of the material.

16. *Do I have to deaccession reformatted nitrate negatives?*

If the nitrate negatives are in…	***Then…***
Stage 1 or Stage 2 of deterioration,	reformat them and inspect the copies. Once you have approved the copies you can dispose of the originals. Don't deaccession the negatives, as you are preserving the images as stable, high quality surrogates.
If the nitrate negatives are in…	***Then…***
Stage 3, Stage 4, or Stage 5 of deterioration and you will be unable to reformat them,	deaccession them and dispose of them as an immediate threat through your hazardous materials coordinator. Negatives that have deteriorated to this level have lost their informational value.

> Refer to *MH-II,* Chapter 6, Deaccessioning, for information on deaccessioning nitrate negatives.

17. *Can I destroy reformatted nitrate negatives?*

You can destroy nitrate negatives that have been reformatted if:

- they have only informational or administrative value
- you have a high quality copy that has been inspected to current standards

Don't destroy nitrates that have high artifactual, evidential, or associational value. See Section A of this appendix for definitions of these types of value.

> ***Destroying nitrate negatives that have only informational or administrative value and that have been copied to current standards isn't a deaccession. This is because you still have the image.***

18. *How do I document reformatted nitrate negatives?*

Document the reformatting of nitrate negatives in ANCS+. For collections in the Collections Management Module, use the Notes field in the Images supplemental record. Enter the replacement negative(s) in this supplemental record.

For collections in the Archives Module, use the Original Duplicates supplemental record. You can use this record at any level in the module. Enter the replacement negative(s) in this supplemental record. Use the location field in this supplemental record to enter the nitrate location.

Use the following, or similar, wording to document the reformatting of nitrate negatives.

If the original nitrate has been destroyed, note:

Original nitrate(s) replaced on (date) *by* (name) *with* (film type, for example, polysulfide toned black-and-white gelatin silver continuous tone film on polyester base) *and checked for quality by* (name) *on* (date). *Original nitrate destroyed on* (date) *by* (name/title of hazardous materials coordinator).

If you are keeping the original nitrate, note:

Original nitrate(s) replaced on (date) *by* (name) *with polysulfide toned black-and-white gelatin silver continuous tone film on polyester base that has been checked for quality*. *Original nitrate was separated and removed to* (location that includes cold storage company, cooperator, or park; address; and phone number).

19. *How do I dispose of nitrate?*

Don't do this by yourself. Instead of throwing hazardous nitrate in the trash or burning it, work with your park or regional hazardous waste coordinator to arrange for the disposition of nitrate and deteriorated cellulose ester film according to EPA guidelines. If you have no hazardous materials coordinator, contact your regional/SO curator for help in locating a NPS hazardous materials coordinator who can assist you or work with your local fire department.

20. *When should I keep original nitrate?*

Don't destroy nitrate if you:

- don't have hazardous waste training and facilities
- don't know the EPA guidelines and your state and local laws on nitrate disposition
- find that your nitrate has high artifactual, evidential, and/or associational value (See Section A.6 and *COG* 19/10, "Reformatting for Preservation and Access: Prioritizing Collections for Duplication.") ***Note*:** If deteriorated beyond stage 3, the nitrate no longer has informational and administrative value. See Section B.13 for an overview.
- find that your nitrate has not yet been duplicated and inspected and the original is in stage 1 or 2 of deterioration (See B.13 for an overview.)
- don't know the values or deterioration state of the original (See Section A.6 and *COG* 19/10, "Reformatting for Preservation and Access: Prioritizing Images for Duplication.")

21. *How do I train my staff to handle, house, store, and manage nitrate and cellulose ester film?*

Work with your regional/SO curator to provide:

- training courses
- details and cross-training under the guidance of trained visual archivists for hands-on experience
- tours and visits to state archives and libraries
- training manuals and Web access

22. *How should I answer requests for access to nitrate?*

Nitrate poses a significant health hazard for researchers***. For health and safety reasons, researchers should work with copy prints, not nitrate or deteriorated cellulose ester films.*** If you receive a Freedom of Information Act (FOIA) request for nitrate or deteriorated cellulose ester film, work with your FOIA officer, regional public relations officer, regional/SO curator, and park superintendent to determine how to proceed without risking the health and safety of staff and researchers.

D. Prevention of Nitrate Fires

1. *What causes nitrate fires?*

At temperatures of 100°F (38°C) or above, quantities of deteriorated nitrate can self-combust, although undeteriorated nitrate doesn't burn until it reaches 266°F (130°C). Self-combustion is caused by the combination of high environmental temperature, low RH, lack of ventilation, flammable material, and a heat producing (exothermic) reaction due to deterioration byproduct gas buildup leading to accelerating deterioration and ever-higher temperatures.

Other, more common causes of nitrate fires include:

- ***sparks*** from:
  - smoking
  - equipment
  - faulty wiring
- ***excessive heat*** from:
  - radiators and space heaters
  - skylights and windows
  - poorly vented attics

2. *How do I prevent a nitrate fire?*

There are several simple rules:

- ***Learn the standards:*** Before housing quantities of nitrate in any structure, obtain the latest National Fire Protection Association NFPA 909, Standard for the Protection of Cultural Resources Including Museums, Libraries, Places of Worship, and Historic Properties. Read it thoroughly and apply it with care. Contact the association at 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101; Tel: 617-770-3000.

- ***Limit quantities*** near public spaces, in general museum storage, in offices, or near heavy equipment, and other fragile, valuable, or flammable materials: Never store quantities of nitrate (more than 20 standard rolls or 20,000 feet of roll film—either motion picture film or professional still photographic negatives on the roll—or 35 pounds or 875 individual still negatives [>4" x 5"]).

- ***Rehouse nitrate*:** House the film as described in Section C.11 and place it in cold storage that meets fire specification standards until you have a chance to reformat and inspect the resulting copies. Never reuse housing that has previously held nitrate film.

- ***Label nitrate clearly*:** Indicate on all boxes, cans, and other containers, that the material inside is nitrate. Label all cabinets with the phrase, "Hazardous nitrate film is contained." Label the room doors with the NFPA Hazard Warning Symbol for nitrate. See Figure M.1.

- ***Inspect regularly*:** Never warehouse nitrate. Inspect the film at least every six months. Monitor the cold storage vault weekly to ensure that it is still operating. If not, transfer the film to your back-up cold storage facility. See Sections C.5 and C.15.

- ***Dispose of deteriorated nitrate*:** Never keep badly deteriorated nitrate (materials in deterioration stages 3-5). Once found, determine if the material is too badly deteriorated to copy (some stage 3 items may be copied). If too badly deteriorated to copy, deaccession and dispose of the nitrate as hazardous material.

- ***Don't project nitrate*:** Never allow projection of nitrate film.

- ***Don't allow ignition sources nearby*:** Never allow any smoking or other sources of ignition or heat (for example: no space heaters or halogen lights) in or near any space where nitrate is housed. The only heating sources allowed in or anywhere near nitrate is steam or water pipe heat kept below 15 psig.

3. *At what temperatures are nitrate materials dangerous?*

According to Photographic Conservator Henry Wilhelm and Eastman Kodak, older deteriorated nitrate film is capable of self-combusting at temperatures as low as 100°F (38°C) when housed at that temperature for prolonged periods. Fires at that temperature, however, are not common. High temperature coupled with the heat generated by the decomposition of gases that can't escape and a low relative humidity can cause these 100°F fires.

Various factors might have halted the self-combustion of these deteriorated nitrate films, including:

- higher relative humidity

- venting of the deterioration gases

- lower ambient temperature

See Sections C.3, C.5, and C.11 for specifics.

Self-Combustion Danger Alert Table

Temperature	**Type of Material**
100°F (38°C)	Older deteriorated nitrate (stage 3 and above) may spontaneously combust at this temperature.
104°F (40°C)	Motion picture film and large quantities of large-sized (>5" x 7") negatives may self-combust at this temperature.
266°F (130°C)	New undeteriorated nitrate may self-combust at this temperature.

Large quantities of nitrate, when housed together, will deteriorate at an ever accelerating rate due to the buildup of heat and acidic gases and may spontaneously ignite, producing toxic gases.

To prevent nitrate film deterioration, fires, and health hazards, don't store large quantities of nitrate in closed, non-venting packages unless you immediately place the packages in cold storage. Larger format negatives in any quantities should be individually rehoused in zeolite or in buffered paper with an open side next to Molecular Sieve packets. Keep all nitrate storage containers, open or venting, and away from other valuable materials. Ideally use cold storage and acid-free buffered or zeolite paper and Molecular Sieve packets configured as described in Section C.11.

4. *What materials pose the greatest risk of causing a nitrate fire?*

The materials at greatest risk of burning are:

- ***roll film*** (motion picture film or professional still negatives on a film roll that have not been cut up into individual images) in quantities of 20,000 linear feet or greater, 20 or more reels of motion picture film, or 35 pounds or more of large format negatives (that is roughly 875 negatives larger than 4" x 5"), aerial film, or X-ray film

- ***bulk packed nitrate***, particularly professional film, in large quantities (more than 35 pounds or 875 negatives) regardless of format

- ***trapped nitrate*** that is tightly sealed in a non-venting drawer or container that doesn't allow the heat and fumes to safely dissipate

- ***unsleeved negatives*** or items not housed individually in buffered paper or board housing materials that can absorb the acidic fumes, such as papers with buffering, Molecular Sieves, activated carbon, and molecular traps to absorb harmful molecules (Again, professional film is particularly dangerous.)

- ***any deteriorated nitrate*** in large quantities (more than 35 pounds), particularly nitrate deteriorated beyond stage 2 (See Section B.13 for a review of stages of deterioration.)

5. *What nitrate materials pose the least risk of causing a nitrate fire?*

Small quantities of undeteriorated still nitrate sheet film housed in individual buffered sleeves within vented or open containers don't pose as significant a hazard. Despite their relative safety, however, they must be housed long-term (more than 5 years) in cold storage as described in Sections C.11 and C.12, preferably outside of the park.

6. *What should I do in case of a nitrate fire?*

First evacuate the building and the area as nitrate burns explosively producing extremely toxic gases. Call the fire department **immediately** from another building. If you still have time, supercool the fire by directly applying large quantities of the coldest water or snow in any reasonable way possible from fire hoses to heavy equipment. **Don't get so close to a nitrate fire that you breathe in the toxic fumes.**

> ***Prevention is the only truly safe way to stop a nitrate fire***. Nitrate fires are rarely put out without first destroying the buildings that house them. While the direct causes of fires are often undiscoverable after a nitrate explosion, they appear most frequently to be heat buildup caused by the accumulation of nitrate deterioration gases due to inadequate housing, venting, and cooling. **Nitrate poses a significant risk to historic structures, staff, and collections.**

- ***Small Fire*:** To extinguish a small nitrate fire, supercool the fire to below 320°F (160°C) through the application of snow, cold water, or carbon dioxide using any tools at hand, such as fire hoses, hoses, heavy equipment, and so forth. Stay at a safe distance from the fire so you won't be at risk of breathing toxic fumes. It may not be possible to put the fire out, as nitrate produces oxygen as it burns. Nitrate can burn under sand, water, halon, and other smothering-based fire extinguishing systems.

- ***Larger Fire*:** It may not be possible to put out a large nitrate fire, particularly if roll or motion picture film is burning in any quantity. Roll and motion picture film fires usually burn until they have totally consumed the film and the surrounding building

7. *What nitrate fires have occurred recently?*

In 1978, nitrate fires at both the International Museum of Photography and the National Archives cold storage facility in Suitland, Maryland, caused many millions of feet of historic motion picture film and still negatives to be destroyed, as well as the structures holding them. Among the works destroyed were the original motion picture negatives of such commercial works as *Strike Up the Band* with Judy Garland and Mickey Rooney.

8. *What do I do if my nitrate or cellulose ester becomes wet during fire fighting or cold storage?*

Wet nitrate film is at great risk for very rapid deterioration. Take the film within 24 hours to a local photographic salvage shop that works with nitrate or air dry or freeze it immediately. According to Deborah Hess Norris in *Disaster Recovery, Salvaging Photograph Collections*, image–bearing gelatin layers in deteriorated nitrate may dissolve in water, leaving only the nitrate base behind. In cellulose ester films, the water may be trapped in the channelized layers, leading to rapid deterioration. Some dyes in nitrate and cellulose ester films may run and bleed pink or blue onto other nearby materials.

Salvage nitrate and cellulose ester materials rapidly if exposed to water. Separate the materials from their housing and air-dry them immediately in a vertical position using clotheslines and wood or plastic clips, such as clothespins. Salvage and air-dry the housing as well in order to preserve the information it contains. Keep nitrate separate from all other materials in a separate room.

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