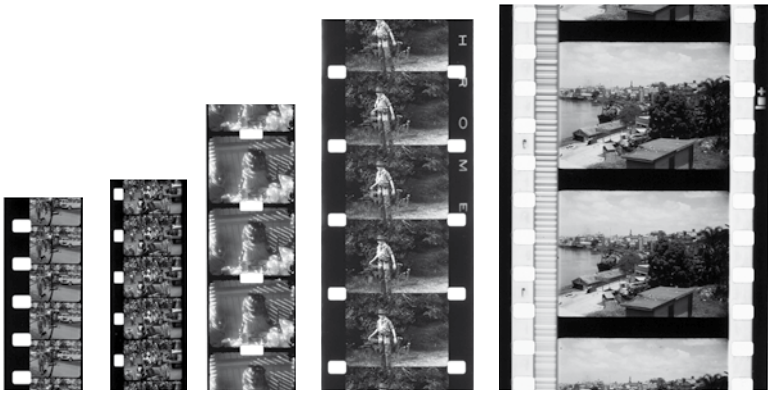
How to care for your motion picture film collection

Home movie and motion picture film collections are a precious source of memories and entertainment, as well as being valuable historic and social records. The State Library of Queensland's film vault contains more than 1,000 motion picture reels from the 1920s to 1970s requiring conservation and careful storage.

State Library conservation staff offer regular clinics, training sessions and workshops which provide group instruction and one-on-one advice on caring for motion picture film, photographs, documents, rare books, maps and a range of other objects and treasures. For information on upcoming events visit **www.slq.qld.gov.au/whats-on**.

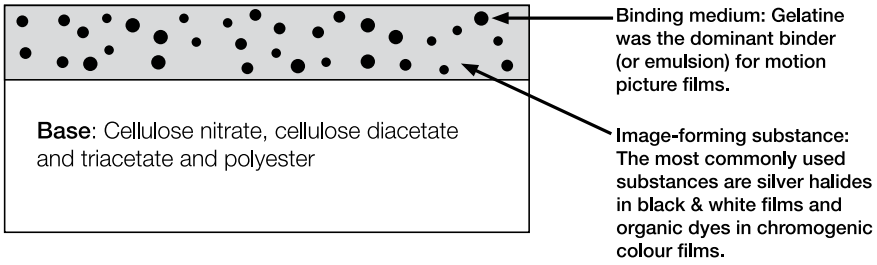
Understanding the composition of motion picture film, assessing variables such as the original manufacturing and processing methods and materials, storage and handling, allows home conservators to calculate and minimise the risks of deterioration.



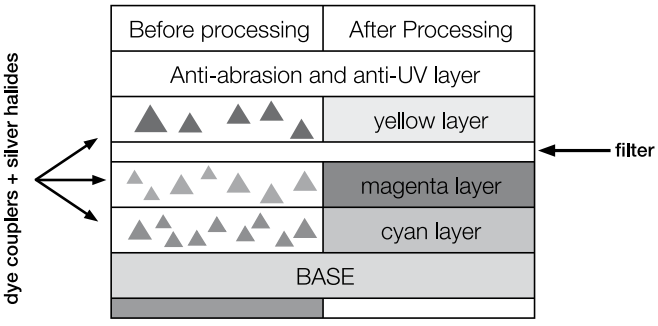
Common film gauges (left to right) standard 8mm, Super 8, 9.5mm, 16mm and 35mm

How is motion picture film structured?

All motion picture film has a basic composite structure (see below), consisting of a binder layer containing the image forming substance on a flexible plastic support. The emulsion or binder, the photographic image and the film base can be affected by different deterioration mechanisms.



An illustration of black and white film structure



An illustration of colour film structure

Binding medium

Gelatine is the most common binding medium, or emulsion, used in motion picture films. Gelatine is water sensitive (known as hygroscopic), which means its stability is closely linked to humidity levels. In humid conditions (approximately 65% relative humidity or higher) gelatine can swell and become sticky or adhesive in quality, this can cause film to stick together or 'block', making it more susceptible to mould growth and insect attack. In very dry conditions (below 20% relative humidity), it can lose flexibility, becoming brittle and potentially flaking off the support layer. The chemical stability of gelatine is greatly reduced as humidity and temperature increases.

Black and white images

Light sensitive silver halides, often referred to as silver salts, are the image forming substance found in black and white film. Black and white images are extremely stable if stored in a pollution-free environment. However, when exposed to common airborne pollutants such as sulphur, nitrogen dioxide or peroxides released from poor quality enclosures, silver halides can be adversely affected, mobilising and moving to the surface of the film, creating an affect known as silver mirroring or localised reddish spots. Overall fading and image discolouration can also occur.

Colour images

The introduction of colour in motion picture film was a period of great experimentation and resulted in many early colour systems. The earliest colour films in the 1930s were based on black and white film and external or embedded colour filters. Unfortunately many forms of commercially available colour film stocks, especially early stocks, do not have stable colour characteristics essential for image permanence.

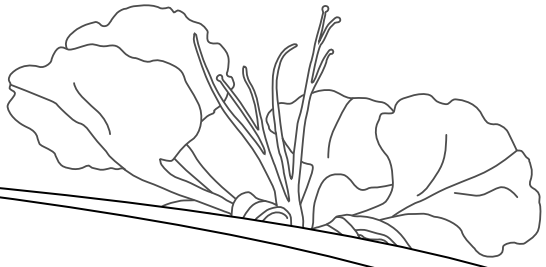
The chromogenic colour process introduced in 1935 and greatly improved over the years, is the most commonly found colour film stock today. The stability of chromogenic film varies greatly. Chromogenic film stocks are manufactured with silver halides, which are replaced by colour dyes during the processing stage resulting in three separate colour dye layers (cyan, magenta and yellow) embedded in the gelatine binder. The chromogenic dyes in most films will decompose when exposed to light and through normal ageing. Exposure to high temperatures, relative humidity and air pollutants (particularly ozone and nitrogen dioxide) accelerate chromogenic dye fading. Dye instability manifests as an overall fading of the image or as a shift in its colour balance due to differences in stability between the different dyes. For example, magenta coloured prints are very common due to the gradual loss of the yellow dye. Modifications in the chromogenic process by companies such as Kodak and Agfa result in differing colour dye losses. Colour tinted and toned black and white film, mostly from the 1900s until the 1940s, is also fairly common, and though this is still a black and white film, the permanence has been altered by the presence of the bleaching and dying chemicals.

How to identify motion picture film stock

Most movies found in home collections are original reversal films. Reversal film is exposed in the camera and then processed using additional steps so that the image forms a positive or transparency (like slide film), rather than a negative image. This is an economical and effective method for amateur use, as there is no need to obtain a film print. However, this also means that extra care should be taken to protect this original item during projection and handling. Some home collections may also include negatives and prints of films. In this case, the negative held is often the original, and the print a copy derived from this original. In some cases only the print copy will exist. Release prints of commercially available films are also commonly found in collections.

Left to right: Reversal (camera original positive, solid black edge), Negative (clear edge), Print (clear edge or solid black edge depending on printing)

Cellulose acetate, cellulose nitrate and polyester (polyethylene terephthalate) are the three main types of film bases or substrates. Many chemical modifications to these bases exist and can affect the rate and type of deterioration that a film will undergo over time. Of most concern are cellulose acetate and nitrate materials. Both acetate and nitrate are modified forms of cellulose and share an inbuilt propensity to deteriorate, particularly when exposed to unsuitable storage conditions.



How to identify and prevent deterioration

Cellulose nitrate film base

The first commercially viable base for motion picture films was cellulose nitrate. Nitrate was first manufactured in 1889 and continued to be used in Australia until the early 1950s. Though nitrate has excellent physical properties, it is chemically unstable and highly flammable. Nitrate motion picture film was responsible for many projection booth and editing room fires. Kept in poor storage conditions (i.e. sustained high or fluctuating temperatures and humidities), its deterioration is accelerated rendering film unusable. In a state of severe deterioration the flash point is low, making the film highly susceptible to combustion, and toxic acidic and oxidizing gases are emitted. Nitrate is considered a hazardous substance and must be handled carefully and, if necessary, disposed of correctly. Refer to the Further Reading list for suitable reading on this subject. There are a number of distinct stages in the nitrate deterioration process which are outlined in the table below.

Stages of cellulose nitrate deterioration[1]

1 Amber discolouration of film base. Noticeable fading of the image, from sprocket areas into centre of film image. A rust ring may form inside metal film cans. Film is still usable but it is important to duplicate films and isolate from other collections at this stage.

2 The film base becomes brittle. Film becomes sticky and blocking can occur.

3 The film base becomes extremely brittle, exhibiting visible bubbles and emitting an acrid odour (nitric acid). Film is rendered unusable from this stage onwards.

4 The film base softens, adhering to adjacent film or enclosure. The acrid odour is very powerful and image fading is significant.

5 The film disintegrates into a brown acrid powder

The rate of nitrate base deterioration is dependent on temperature and relative humidity and is autocatalytic in nature. This means that the higher the temperature and humidity levels are, the faster the rate of decomposition and once deterioration begins it cannot be stopped. To slow down the rate of deterioration, temperature and humidity levels must be lowered significantly. Guidelines on how this is best achieved are outlined in the Storage Recommendations section.

Cellulose acetate (diacetate and triacetate)

Cellulose diacetate, known as safety film, was introduced in 1923 as a less flammable and combustible alternative to nitrate. It was in use until cellulose triacetate began to dominate the market in the 1940s. A number of other acetate modifications were also tried but triacetate became the main film stock from the early 1950s until polyester became popular in the 1990s. Some amateur gauges (e.g. 16mm) were produced on acetate as early as 1909.

Cellulose acetate is the most common film stock found in private and institutional film collections. Often it is in poor condition due to its inherently unstable chemical structure. The most damaging deterioration is the breakdown of the acetate base into acetic acid, commonly known as vinegar. The damage is known as vinegar syndrome and is identified by the characteristic vinegar smell. There are a number of distinct stages in the deterioration process, which are outlined in the table below.

Stages of cellulose acetate deterioration

Stage *Deterioration description*

1 Film gives off a vinegar (acetic acid) odour, early signs of base shrinkage and embrittlement. Film is still usable but it is important to duplicate if the film is considered important. Affected film should be isolated from other collections at this stage. Regular testing of acidity levels with A-D strips (see Suppliers List) should begin at this stage. If possible, place film in suitable cold storage to slow down deterioration.

2 Film begins to distort dramatically and shrinkage increases. Shrinkage greater than 1% is problematic for motion picture film.

3 Base embrittlement and shrinkage increases, film in this condition can be easily damaged due to lost flexibility. Bubbles form between emulsion layer and base. *Film is rendered unusable from this stage onwards.*

4 As the gelatin binder does not shrink at the same rate as the base, dimensional stress occurs causing the gelatine to separate from the base. This affects the image quality significantly. Formation of white crystals can occur on the film surface

5 Film becomes either flaccid or crystalline and emulsion layer becomes sticky

As with nitrate base deterioration, the rate of acetate base deterioration is also temperature and relative humidity dependent and autocatalytic in nature. Please refer to the Storage Recommendations section for appropriate environmental conditions.

Polyester

The introduction of polyester (polyethylene terephthalate) marked a major advance in the technology of film supports. Polyester was invented in Great Britain before World War II and was developed as a film support in the mid 1950s. It has superior physical properties and is considered to be chemically stable. It has only been in widespread use since the 1990s, but was previously common in the form of 16mm release prints and as small gauge amateur film such as 8mm. It is now used widely for film prints including 35mm. It is the recommended film support for duplication of acetate and nitrate films.

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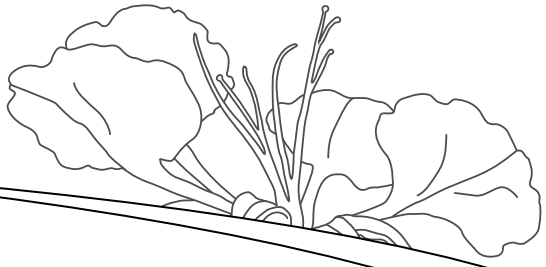
[1] Cummings, James W., et al., "Spontaneous Ignition of Decomposing Cellulose Nitrate Film", *Journal of the SMPTE*, 54 (March 1950), pp. 268-274.



Sound

Sound tracks using magnetic and optical systems can be found on many home movies. Magnetic audio tracks, essentially read in the same manner as an audio tape, were produced either during manufacture directly onto raw film stock, or were striped onto the film by hand assisted striping devices. This combination is complex to preserve, as magnetic tracks have conflicting preservation requirements to the celluloid film on which they reside. Magnetic tracks must be kept away from any magnetic fields around the home and should be kept under moderate temperatures and humidity. Magnetic fields are generated by appliances such as televisions. Optical sound tracks are produced by photographic exposure onto the film and are most commonly found on commercial release prints. Since these are created by the same photo-chemical process as the image itself (halides and dyes etc.) they need no additional preservation precautions but are subject to considerations such as dye and image fade and scratching etc.

How to store your motion picture films

It is well documented that proper climate control leads to significant improvement in the chemical stability of both acetate and nitrate film, and chromogenic colour images. Lower temperatures and drier conditions slow down the degradation rate appreciably. Stringent ISO standards are available for film storage (these are summarised below) and many institutions with large film collections and well funded preservation programs use these standards as guidelines, adapting them to their own collection requirements. As the cold storage vaults recommended by the ISO standards are expensive and costly to maintain, this approach is not practical for most small organisations and home collectors and creating a stable environment can prove challenging.

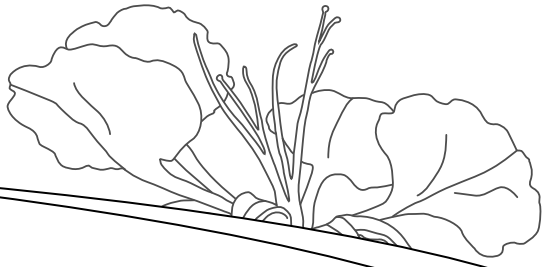
Listed below are a number of simple, low tech methods of improving your film's storage and handling conditions.

- Minimise fluctuations in temperature and relative humidity by locating storage areas away from external walls and sources of heat and moisture such as kitchens and bathrooms.
- Ensure storage areas have good air movement, avoiding stagnant air pockets. The use of strategically positioned fans can assist with this.
- Be aware that significant daily fluctuations can occur when air conditioning units are switched on during the day and off at night.
- Create a buffer against ambient conditions by placing films in archival quality film cans.
- Keep area clean and regularly check for pest and mould activity. Information on pest and mould control is available from the State Library's Conservation Unit.
- Re-house films by obtaining new plastic cans that meet the Photographic Activity Test (ISO 14523) (such as those made from polypropylene or polystyrene, please see Suppliers List). Discarding old metal cans and cardboard boxes will help create a relatively chemically inert micro-environment.
- All foreign matter such as paper and rubber bands should be removed, but don't forget to store copies of any useful information about the films.
- New leader can be attached to the start and end of films for added protection, and clear labeling should be carried out on both the film leader and the film can.
- Store cans horizontally on open metal shelving to maximize air movement. Cans should not be over-stacked, ensuring pressure on the films is minimised.
- Domestic fridges or freezers can be used to create a cold storage environment for small numbers of films. Specially designed individual packaging of films is essential to minimise risk of condensation. For further information please contact the State Library Conservation Unit.
- If possible ensure stable material is stored separately to deteriorated film.

How to handle your motion picture films

Surface dirt and other residual matter can not only commonly affect the appearance of a film, but also trigger deterioration. Dust is attracted to film through static electricity, and dirt and sticky residue build up over time such as during use on projector mechanisms and by the effects of decomposing film splicing tape. The cleaning of film should be approached with caution to ensure that further damage will not be incurred. Please seek professional advice first.

Considerable physical damage can occur to films if not handled correctly. Films should be checked for signs of physical damage by carefully examining over a light box with film winding arms, or by rewinding the film on a projector (without passing through the film gate). Tears, perforation and edge damage can all cause further destruction if not physically repaired before projecting. Projection equipment should be checked and thoroughly cleaned before use, paying special attention to the film gate. Scratches to the film (black vertical lines represent 'base scratching' and white or coloured lines represent 'emulsion scratching') can be avoid with careful projection, projector maintenance and good handling techniques. When winding a film, be careful not to 'cinch' it by allowing the film to tighten suddenly. The effects of cinching can be seen as horizontal scratches and can also be incurred while the film is in transit if it is wound too loosely.



How to duplicate your motion picture films

Creating access copies of the films for viewing such as on video tape and DVD or as a digital file (see Film Transfers List), will help protect original films from the effects of over-use. Storing film copies separately to the original films, such as in separate areas of the house or off-site to your home, will assist in creating a back-up system in case of disasters such as flooding and fires. After a transfer is made, it is very important to preserve the original film material. It is also likely you will need to create further copies on new home media in the future due to the constantly evolving technology market and the relatively short commercial and physical life span of digital and analogue video media.

Appendix 1.

Instructions for polarization test

(*taken from* Monique Fischer, *A Short Guide to Film Base Photographic Materials: Identification, Care, and Duplication* (Andover, MA: Northeast Document Conservation Center), 2007
http://www.nedcc.org/resources/leaflets/5Photographs/01ShortGuide.php)

When viewed between cross-polarized filters, polyester and other highly birefringent materials exhibit red and green interference colours like those seen on soap bubbles. Cellulose nitrate and the cellulose acetate film do not show these interference colours. The polarization test can be performed with the simple viewer described below.

To use the viewer unfold the viewer and place a corner of the material in question over one polarizing filter. Close the viewer and hold the viewer up to a light source. Tilt viewer back-and-forth and side-to-side, red and green interference colours will be most apparent in clear areas. If a material is badly deteriorated, examine it on a light table with one polarizing filter underneath it and one on top of it.

Instructions for making a viewer

- Tape together two pieces of mat board along their long edge.
- At the left corner of each mat board split an area slightly larger than the polarizing filter.
- Cut a hole in each split area smaller than the polarizing filter.
- Slip polarizing filters into each split board. Be sure to place the filters so that they are almost at cross polars to one another. This will be at the point at which they block the most light passing through them.
- Apply double-sided tape to reattach the split boards and to hold the filters in place.
- Polarizing filters are available at toy stores in many children's science kits or see Suppliers List.

Fact sheets

Cellulose nitrate

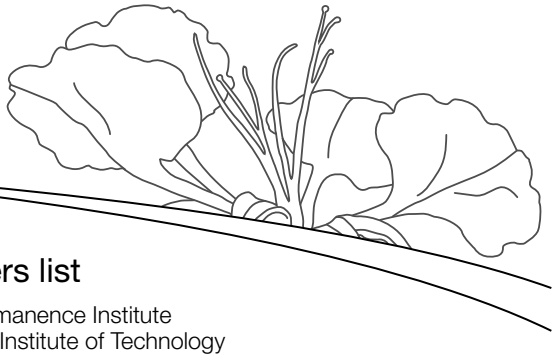
Approx. period of use	• 1889 – circa early 1950s
Common formats	• Professional 35mm • 17.5mm film which was split from 35mm film and other very rare gauges may exist.
Summary of deterioration characteristics	• Silver image decay • Nitrate base decomposition • Gelatine binder degradation • Mould damage • Offgassing of acidic gases can adversely affect surrounding materials. • Deterioration can occur from use of acidic enclosures and exposure to air pollutants.
Recommended storage environment	Nitrate ISO 10356: • Max. temperature 2°C • RH (relative humidity) 20-30%. If base degradation has begun, freezing is recommended.
Identification methods	• See characteristic deterioration mechanisms and deterioration stages outlined above. • Destructive testing can be used, including the flammability test but these tests are not recommended for home use.

Cellulose acetate

Approx. period of use	• 1912 – 1940s – diacetate • 1940s – to present – triacetate
Common formats	• 9.5 mm (colour & B&W) • 8 mm (colour & B&W) • Super 8 (colour & B&W) • 16mm (colour & B&W) • 70mm (colour & B&W) • 28mm (B&W) • 17.5mm film which was split from 35mm film and a multitude of obsolete gauges
Summary of deterioration characteristics	• Silver image decay • Acetate base decomposition known as vinegar syndrome. Level of deterioration can be assessed with A-D strips (see Suppliers List). If A-D strip reading 2 or greater freezing and prompt duplication is recommended. • Mould damage • Colour dye decomposition (colour films) • Offgassing of acidic gases can adversely affect surrounding materials. • Deterioration can occur from use of acidic enclosures and exposure to air pollutants.
Recommended storage environment	Black & white film – ISO 18911: • Temperature 2-7°C • RH: 30 -50% (depending on storage temperature) Colour film – ISO 18911: • Max. temperature 2°C • RH: 30%. • Freezing is considered the best option: -10°C and max. RH 50%.
Identification methods	• See characteristic deterioration mechanisms and deterioration stages outlined above. • Destructive testing not recommended for use at home. • Polarization test: No evidence of interference colours. Please refer to Appendix 1. for instructions on polarization test.

Polyester (polyethylene terephthalate)

Approx. period of use	• Invented before WWII, in use as early as the 1950s, but not in common use until 1990s – to present
Formats	• Small gauge, such as 8mm (colour) • 16mm release prints (colour & B&W) • 35mm release prints (colour & B&W)
Summary of deterioration characteristics	• Silver image decay (B&W film) • Colour dye decomposition (colour film) • Mould damage
Recommended storage environment	Black & white film – ISO 18911: • Max. temperature. 21°C • Max. RH: 50% Colour film – ISO 18911: • Max. temperature 2°C • Max. RH: 30%. • Freezing is considered the best option: -10°C and max. RH 50%.
Identification methods	• Polarization test: Polyester exhibits red and green interference colors like those seen on soap bubbles (see Appendix 1.)



Further reading

Adelstein, Peter Z., *IPI Media Storage Quick Reference*, (Rochester, NY: Image Permanence Institute), 2004

Conservation Online (CoOL): http://palimpsest.stanford.edu

Film Forever (Home Film Preservation Guide Sponsored by AMIA) http://www.filmforever.org

Little Film (history and preservation information on small gauge film): http://littlefilm.org

Monique Fischer, *A Short Guide to Film Base Photographic Materials: Identification, Care, and Duplication* (Andover, MA: Northeast Document Conservation Center), 2007 http://www.nedcc.org/resources/leaflets/5Photographs/01ShortGuide.php

National Film Preservation Foundation – Mellon, *Understanding Film and How it Decays* www.filmpreservation.org/preservation/fpg_2.pdf

National Film and Sound Archive, *How to Care for your Film* http://www.nfsa.afc.gov.au/Screensound/Screenso.nsf/HeadingPagesDisplay/Preservation?OpenDocument (or go to http://www.nfsa.afc.gov.au/screensound/screenso.nsf and choose 'Preservation' from the top menu)

National Fire Protection Association, *NFPA 40 – Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*, (NFPA), 2000

National Park Service, *Conserve-O-Gram No.2/22 – Disposal of Cellulose Nitrate Film* (Washington D.C: National Park Service), August 2004 http://www.cr.nps.gov/museum/publications/conserveogram/02-22.pdf

Reilly, J.M., *IPI Storage Guide for Acetate Film* (Rochester, NY: Image Permanence Institute), 1996 www.imagepermanenceinstitute.org

Useful standards

Please note standards are updated regularly so ensure you are using the most current standard.

ISO 10356 *Cinematography: Storage and handling of nitrate-base motion picture films* (Geneva: International Organization for Standardization), 1996

ISO 18911 *Imaging materials – Processed safety films – Storage practices* (Geneva: International Organization for Standardization), 2000

ISO 14523 *Photography: Processed Photographic Materials – Photographic Activity test for enclosure materials* (Geneva: International Organization for Standardization), 1999

Suppliers list

Image Permanence Institute
Rochester Institute of Technology
70 Lomb Memorial Drive
Rochester, NY 14623-5604 USA
Website: www.imagepermanenceinstitute.org
Product: IPI A-D strips – Test strips used to measures free acidity produced by degrading cellulose acetate film

Production Shop
55 Wellington Rd.
East Brisbane, QLD, 4169
Telephone: (07) 3896 1000
Product: Filters for Polarization Test

Tuscan Industries
PO Box 1593,
Strawberry Hills, NSW, 2012
Telephone: (02) 9699 2422
Products: Polypropylene 16mm film cans and cores, polystyrene 8mm cans and reels

Kodak Australasia
173 Elizabeth St
Coburg, Vic, 3058
Telephone: (03) 8371 8524
Products: 16mm Cream Leader, 8mm leader, splicing tape, film cement

Film transfers list

Nano Lab
36 Grant St
Daylesford, Vic 3460
Telephone: 0400 748 864
Email: richard@nanolab.com.au
Website: www.nanolab.com.au
Type of transfer offered: Telecine service to transfer processed Super 8 or Standard 8 films to digital via frame-by-frame film scanning system. Output to digital computer file only- not to tape. Uncompressed digital files also offered.

DVD Infinity
PO Box 86
North Sydney, NSW 2059
Telephone: (02) 9906 6383
Email: info@dvdinfinity.com.au
Website: www.dvdinfinity.com.au
Type of transfer offered: Transfer of Super 8, Standard 8mm, 9.5mm & 16mm, video(broadcast, professional and domestic formats), photos, 35mm slides and negatives. Digital via frame-by-frame film scanning system.

Video-8 Broadcast
19- 21 Dickson Ave
Artarmon, NSW 2064
Telephone: (02) 9438 4144
Email: sales@video-8.com
Website: www.video-8.com
Type of transfer offered: Broadcast transfer facility that uses a Rank-Cintel 'flying-spot' (continuous motion) scanner. Transfer of Standard 8mm, Super 8, 16mm and 35mm.

Need further information?

State Library of Queensland, Cultural Centre, Stanley Place, South Bank
Conservation Unit, Collection Preservation: 07 3840 7779
Reference Services: 07 3840 7810
John Oxley Library: 07 3840 7880
conservation@slq.qld.gov.au
www.slq.qld.gov.au

Queensland Government