Preservation and Reuse of Film material for television

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Summary

Future television production systems will require easier access to archival film material in an electronic digital form, for both preview and production purposes. In order to meet these requirements, broadcasters will need to transfer large collections of film material – a very time-consuming and expensive operation. Regrettably, some of the film material in their vaults may already have started to degrade, due to adverse storage conditions.

This document offers comprehensive guidelines to broadcasters on the handling, storage and reuse of motion picture film material for television production, both now and in the future. The telecine transfer process is discussed in detail, with special attention being given to its replay and correction properties. The document also discusses the effects of storage conditions on film material, and the problems encountered when handling endangered, degraded, material in a broadcast environment. There is specific advice on how to check, preserve and store film material. Special attention is paid to the so-called "vinegar syndrome", which is considered the major threat to the future reuse of acetate-based film material.

The EBU working group which produced this document would like to acknowledge Eastman Kodak Company, the Image Permanence Institute and the Rochester Institute of Technology for the facts and figures on motion picture film properties and behaviour that are quoted here.

Basic facts and figures have been taken from these two publications:

- Kodak publication, No. H-23X: **The Book of Film Care** [1];
- Image Permanence Institute: **IPI Storage Guide for Acetate Film - 1993** [2].

Chapter 1
Introduction

The value of television programmes, produced on film, is impossible to estimate. Many of these films contain cultural and historical recordings that are major assets for the future. The film medium itself is independent of any television system and will be playable in all present and future television standards. This makes the keeping of film of extreme importance to the broadcaster. Proper storage, preservation and handling of film will determine its lifetime for future use.

Most broadcasters have programmes originated on film that are now more than thirty years old. These programmes exist on a wide range of acetate-based film materials, such as camera originals (negative and reversal), intermediate films, and prints made from negatives, intermediates or reversal films They can be in black & white or colour. They have accompanying sound tracks either as COMOPT (Combined Optical), COMMAG (Combined magnetic stripe) or SEPMAG (Separate magnetic sound).

Historically, because broadcasters have required immediate access to film material, they have often stored film in conditions that can give a usable life – for some films – of only 10 years. Unfortunately, the temperature, humidity and air purity conditions inside these storage areas have caused not only image deterioration but also serious deterioration to acetate-based film and sound material. Because of the problems being encountered by some film archives from these storage practices, the EBU has revised its advice on film storage. EBU Recommendation R101 [3] gives specific advice on storage of both fresh film and also actively degrading film and sound material in the archives.

The EBU has additionally produced this document, Tech. 3289, to support Recommendation R101 with information on the basic properties of film material, aspects of its degradation, as well as the preservation, handling and reuse of archival film. The present document also covers the role of archival film in future television production and archiving.

If properly stored and handled, film may have a useful life of several hundred years. Film quality is often higher than television quality and there is little prospect that film will not be replayed on any future television standards. That is, if the film material is in good condition. The major threat to acetate-based film materials is the "vinegar syndrome" but there is also the risk of physical defects from splices and scratches as well as colour dye fading. Many broadcasters consider that converting to a video recording is a cost-effective alternative to copying to another film material for protecting and preserving material on endangered film. This does however mean that the potential of film for reuse may be lost.

The transfer of large film collections is a time-consuming and labour-intensive process on high-cost equipment and should therefore be considered against short-term and longer-term production requirements. To avoid multiple transfers, it is important to consider demands of future exploitation as well as the immediate needs for production. The image quality and flexibility of the transfer for future use is determined by the telecine or film scanner configuration and the properties of the system-defined recording formats. The currently recommended video format (i.e. ITU-R BT.601 [4]) prefers an uncompressed form in order to maintain the image quality.

Future high-definition production formats could exploit more of the information from film, but there are uncertainties about when and which of several proposed formats will become widely adopted as production standards, although some countries are already producing and delivering HDTV. The individual broadcasters will therefore have to decide whether to exploit their film material by integrating HDTV in its migration strategy now, or meeting requests on a case-by-case basis.

Good storage conditions and professional handling will keep open the options for making transfers to any future production formats.

Chapter 2
The nature of motion picture film

Unexposed motion picture film is a plastic-base material, coated with an image-forming layer. Most of the compounds in film are organic in nature and are sensitive to heat, moisture, light and air pollution, hence there is an unavoidable degradation process that will affect the image layer itself and the physical properties of the base material. The image stability and physical properties of stored film are therefore very much dependent on the environment in which film is handled and stored.

2.1. The image layers

The image-forming layer (emulsion) is mainly composed of gelatine with a suspension of light-sensitive silver-halide crystals. In addition, most colour films contain "colour couplers", complex chemicals that are the precursors of the image dyes. After exposure and processing, the result is either a black & white image formed from silver, or a colour image formed from colour dyes.

2.1.1. Silver images

In the case of black & white stock, the image-forming layer contains metallic silver. This layer is susceptible to fading over time. It is particularly sensitive to humidity and temperature, although the latter plays a lesser role in this process. Moisture is more important because it creates the conditions for the degradation of metallic silver. Pollutants and contaminants have significant effects on this process of change. Residual chemicals, especially thiosulphate, can also cause degradation of silver images.

2.1.2. Dye images

Almost all colour films employ the subtractive system of colour reproduction – using cyan, magenta and yellow dyes to represent the red, green and blue content, respectively, of the scene. The processed colour image layer consists of these colour dyes, suspended in gelatine. The colour dyes are complex organic compounds with different degrees of stability and are susceptible to heat and moisture, which can lead to their destruction. Even at normal room temperatures and humidity, significant fading can occur in a few years. High temperatures and high humidity will speed up the chemical reactions leading to dye destruction. Because the different colour dyes do not fade at the same rate, the colour balance and contrast of an image can be significantly changed. Modern colour films have a much better dye stability than earlier films Some earlier types of colour film required chemical stabilization of the dyes, especially the magenta dye.

2.2. Film base materials

The film base needs to be transparent, durable, stable and strong enough to carry images through all the different working processes that film undergoes.

2.2.1. Cellulose nitrate

This film base was excellent for flexibility, strength and clarity, but it was chemically related to guncotton – making it unstable and highly flammable. Therefore, it was a serious fire hazard and had to be handled with the utmost care.

Broadcasters are advised not to store nitrate film

2.2.2. Cellulose acetate

The cellulose triacetate support, often called "safety base" or just "acetate", had replaced the nitrate base by the 1950s and has been the most commonly used film base since the introduction of television services. The acetate base is much less flammable and does not represent a major fire hazard. However, acetate base is susceptible to degradation through the action of moisture normally present in the acetate plastic. This is known as the "vinegar syndrome" (*see Section 4.3.*).

2.2.3. Polyester

Polyethylene terephthalate, usually known as "polyester", has almost completely replaced acetate as the base material for print films and is currently used for some intermediate films. Camera negative films are still principally on an acetate base. Compared to acetate, polyester is a stronger material, less sensitive to moisture and is considered chemically and dimensionally more stable.

2.3. Magnetic sound support

Magnetic sound tracks used in television may be COMMAG or SEPMAG. With COMMAG, a stripe magnetic recording medium is coated on the picture film itself, whilst SEPMAG is a separate magnetic recording medium. SEPMAG may be on either acetate or polyester base material. Acetate was commonly used until the early 1970s, when polyester superseded it. The acetate-based SEPMAG has the same chemical properties as the acetate used for picture film and will therefore have the same problems. An important extra factor is that the iron oxide coating acts as a catalyst for the degradation of acetate base, so acetate-based SEPMAG will be more susceptible to degradation, with a doubled rate of decomposition. Even the presence of iron oxide on a polyester base can catalyse the degradation of acetate-based material, if it is in close proximity.

Chapter 3
Film image degradation

Image degradation begins from the time the film is processed. The image-forming layer is affected by variables, such as residual chemicals after development, air pollution, light, temperature and humidity. Proper storage conditions are vital. It is impossible to provide conditions for storage that will prevent image degradation entirely, but it can be reduced to a low level that may be considered acceptable.

3.1. Image degradation in black & white films

It is often believed that silver images in motion picture films do not degrade. This is not true: in reality silver images do fade. Temperature only plays a minor role in silver-image fading. Humidity however is more important because it encourages oxidation (corrosion) of metallic silver. The effect of humidity is particularly important in the presence of pollutants. Contaminants in the air like peroxides, ozone, sulphides and contaminants arising from poor quality enclosure materials are the substances that actually react with silver images to cause fading.

3.2. Image degradation in colour films

3.2.1. Colour dye fading

Dye fading is a natural ageing phenomenon which happens to the organic dyes used in colour film. The different dyes have different fading characteristics. Fading is a loss of density, which reduces the contrast of each individual dye layer. This results in errors in the colour balance and the colour tracking of the image.

The causes of colour dye fading are:

- Characteristics of the colour dyes used, i.e. their stability relative to the other dyes and whether they change image contrast more quickly;
- Heat energy which the film is exposed to;
- The moisture level during storage;
- The impact of air pollution emitted inside the container and in the storage vault.

The fading and ageing characteristics of colour dyes can be predicted when the type and version of the film stock, and the history of the temperature and relative humidity of storage, are known.

Various manufacturers e.g. Eastman Kodak, Fuji and Agfa-Gevaert, have recorded these characteristics for their products. They differ considerably.

Fading also varies between different products from the same manufacturer; for instance, the dyes in colour print films fade faster than the dyes in colour negative films. The dyes in Ektachrome colour reversal film fade faster than those in Kodachrome.

3.2.2. The visual effects of dye fading

Fading is usually proportional to the amount of dye present, leading to a decrease in contrast of the dye. Furthermore, each of the three image dyes fades at a different rate. The effects of dye fading are therefore a change in overall density, a change in colour balance and a loss of colour tracking. Tracking errors appear as different colour casts in high- and low-light areas of the image.

A density loss of 10% (0.1 from an original density of 1.0) in one or two of the three layers of print material will result in a change in colour balance which will be just perceptible, especially under television viewing conditions. The change in a re-graded image after a density loss of 0.2 will be perceptible to the trained eye, but not noticeable to the average viewer. The net result of a density loss of 0.4 is definitely noticeable, and is normally noticeable and considered unacceptable in traditional film printing and projection.

For films that have a grading history, a colour analyzer can be used to identify the actual amount of dye fading. Such an analyzer, found in any film laboratory, will show the density losses expressed in known printer light values and will simulate the appearance of a re-graded (retimed) film copy. If the analyzer indicates a 20 - 30% change of printer lights from earlier printer-light settings, a fully re-graded copy of the film will be needed. Although a telecine will show what can be corrected, it will not – unlike an analyzer – give values for the changes in colour dye densities (*see Section 11.7.1.*).

3.2.3. The effects of temperature

Specific information on individual films can be obtained from the various manufacturers. The general effect of temperature on relative storage time at constant relative humidity can be found in *Table 3.1*.

Table 3.1
General effect of temperature on dye fading rate at 40% constant relative humidity.

Storage temperature	Relative dye fading rate	Relative storage time
30°C	2	½
24°C	1	1
19°C	½	2
16°C	¼	3½
12°C	1/5	5
7°C	1/10	10
-10°C	1/100	100
-26°C	1/1000	1000

3.2.4. The effects of humidity

The water content in the emulsion of a photographic film and the relative humidity of the ambient air are closely related. Consequently, the relative humidity of the ambient air is usually taken as the relevant parameter for the water content of the emulsion. High humidity of the ambient air results in higher water content in the emulsion. This leads to a higher degree of decomposition of the organic dyes due to hydrolysis. The general effects of relative humidity on the relative storage time of dyes are shown in *Table 3.2*.

Table 3.2
Effect of humidity on dye fading rate.

Relative humidity	Fading rate	Relative storage time
60	2	½
40	1	1
15	½	2

A high relative humidity has the further disadvantage that it encourages the development of micro-organisms such as moulds. Gelatine, which constitutes the binding agent of the emulsion, is an unstable material under very humid conditions. A relative humidity in excess of 60% RH, becomes dangerous in this respect (*see Section 6.6.*).

3.2.5. The effects of light

Virtually all colour dyes are susceptible to fading if exposed to light, but for motion picture film this is not normally a significant factor. The actual amount of time that light shines through a motion picture print, even if it is projected hundreds of times, is only a few minutes. Film is normally stored in lightproof containers.

3.2.6. The effects of air pollution

Gaseous impurities such as sulphur dioxide, hydrogen sulphide, peroxides, ozone, ammonia, acid fumes and nitrogen oxides may cause deterioration of the base and image. Solvents or paints can also cause deterioration of the film base or degradation of the image, for example dye fading (*see Chapter 6*).

3.2.7. The effects of processing

All films must be processed to the recommended standards of the manufacturer. Residual chemicals after development (such as Thiosulphate) will cause degradation and should therefore be washed out. Residual silver left in the processed film is also a concern. ISO 18917 [5] and ISO 10636 [6] give details and values. There are two important tests to assess the potential for instability of silver images in black & white films. The *Hypo Test* indicates whether the material has been washed adequately. The *Residual Silver Test* indicates whether the image has been fixed sufficiently.

3.2.8. Dye stability of old and new film stocks

Modern colour film stocks have better dye stability than older film stocks. All major film manufacturers introduced low-fade dyes in the early 1980s. The stability of the dyes in camera negative film and colour intermediate film is known to be better than that of print stocks. Colour negatives before the mid-1970s are less stable than today's colour negative stocks. Colour release print film made prior to 1980 is less stable. Intermediate stocks are generally known to have better stability than release print stocks. However, the intermediate stock called *Colour Reversal Intermediate* (CRI) used between the mid 1960s and late 1980s is known to have a low stability.

Some practical examples of severe dye fading of older film stock, which have been stored since 1976 at 18ºC and 50% RH, are given in *Table 3.3*. This shows the approximate periods of time to reach the specified density losses – ΔD – of the least stable dye at density 1.0.

Table 3.3
Examples for dye fading of older film stocks at 18° and 50% RH.

Film Stock	Type	$\Delta D = 0.1$	$\Delta D = 0.2$	$\Delta D = 0.4$
Reversal	Ektachrome. Comm. 7252	3 years	7 years	18 years
Reversal	Gevachrome II T 700	6 years	14 years	
Negative	ECN II 7247	20 years		
Print	ECP 7381	4 years	11 years	18 years

The effect of severe dye fading in older film stocks should be reduced to some extent, however, by keeping to more stringent storage conditions, e.g. 5°C and 25 - 30% RH, as recommended in *Section 8*. As a result, the time period for reaching a loss of 10% ($\Delta D = 0.1$ from an original 1.0) of the least stable dye, which is just perceptible to the trained eye under television viewing conditions, should be somewhat below 100 years.

Colour film materials delivered after the early 1980s are expected to last for a much longer time. This is especially true when stored under conditions of low temperature and low humidity. For example, Eastman-Kodak predicted in 1987 that, for typical camera originals and print stocks kept in the dark at 7°C and 40% RH, it would take 200 - 400 years for the loss in the yellow (limiting) dye at density 1.0 to reach 10%. Present-day film materials with low-fade dyes, stored under such conditions, should at least reach this expectancy if not surpass it.

Chapter 4
Film base degradation

All film bases are manufactured from materials that are sensitive to their environment and degrade by hydrolysis and oxidation. In the presence of moisture, cellulose-based materials are known to form acids. In cellulose nitrate – usually referred to as just "nitrate" – nitric acid is formed: with acetate-based materials, acetic acid is formed. If sufficient acid is present, then the physical properties of the film will be affected. The material will dry out and shrink. This will affect the usable lifetime of the material. The more recent polyester support is a petroleum-based product that is less sensitive to degradation caused by environmental conditions.

4.1. Problems specific to nitrate-based films

Nitrate base was used for 35mm motion-picture films until acetate base materials replaced it during the early 1950s. 16mm and other narrow gauge film stocks have rarely been made on anything other than safety bases. Nitrate-based films are often found in old archives and must always be treated with the greatest care since they could be in an unstable condition and are highly flammable. They should be copied as soon as possible.

4.2. Problems specific to acetate-based films

Acetate is the most common base material for film that has been used by broadcasters since the introduction of television services and is still used for camera negative films. Acetate does not represent a fire hazard, but represents a major risk because of base degradation, often called "vinegar syndrome". Any film showing signs of vinegar syndrome is likely to have become physically degraded and may become damaged if handled without special precautions.

The acetate stocks currently in use are known to be no different from old acetate material.

4.3. Vinegar syndrome

The "vinegar syndrome" began to be noticed in broadcasters' archives by the early eighties. Acetate base materials are subject to a chemical reaction with the moisture absorbed by the acetate support. This reaction (acetate degradation) releases acetic acid and is prompted by heat and moisture. The reaction can be accelerated by the presence of a catalyst. Affected film material loses its plastic properties and dimensional stability. Another effect is the presence of plasticiser crystals on the film surface.

The rate of reaction is very slow, as long as the moisture content is low and the film is kept at a low temperature. With newly-processed film, the level of acetic acid is low. Then it gradually builds up over a long period of time. After the acid level has increased to a certain level, the reaction rate increases, suddenly becoming very rapid. At this onset, called the autocatalytic point, the reaction will feed on itself and the more advanced the reaction becomes, the more the reaction rate is accelerated by the presence of acetic acid *(see Fig. 4.1 and Table 4.1)*. The typical symptom is the smell of vinegar, which indicates that the acetic acid has come to the surface of the film base and is being released into the air. All acetate-based materials are susceptible to this deterioration. When it happens depends on the storage conditions in which the materials are kept. The process cannot be stopped or reversed but it can be slowed down significantly by storage in cold and dry conditions.

Fig. 4.1 and *Tables 4.1* and *4.2* are published by the Image Permanence Institute and are based on the results of a research programme. It is important to bear in mind the fact that these results are based on ageing experiments with fresh non-magnetic film in sealed containers under constant storage conditions. The rate of degradation for an individual roll of film in a broadcast archive will be determined by its individual storage history, i.e. its storage environment, amount of time out of the archive, etc *(see Section 8.6.)*. Thus environmental factors can influence whether the induction period is long (perhaps centuries) or short (just a few years).

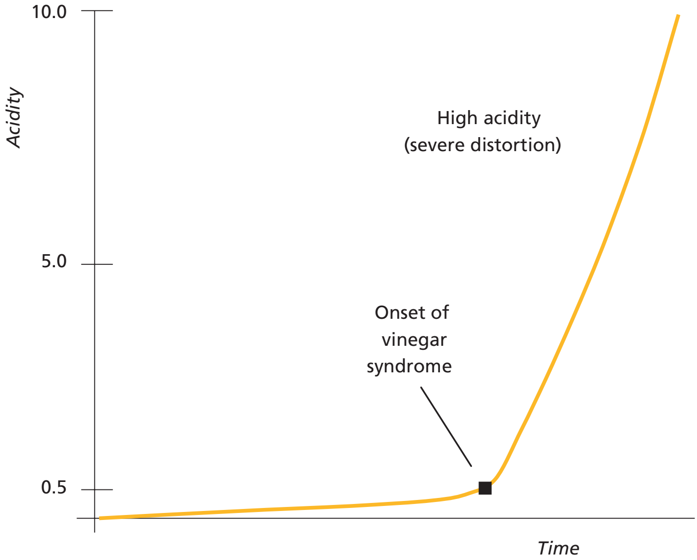

Figure 4.1
Time versus acidity diagram for acetate film.
(IPI Storage Guide for Acetate Film, 1993 [2])

Table 4.1
Reaction time for fresh film to reach the onset of vinegar symdrome.

Storage conditions		
Temperature	**Relative Humidity**	**Onset of reaction**
24°C	50%	30 years
21°C	50%	40 years
18°C	50%	50 years
13°C	50%	100 years
5°C	20 - 30%	600 years

Table 4.2
Approximate time to increase vinegar onset acidity level from acidity level 0.5 to 1.0.

Storage conditions		
Temperature	**Relative Humidity**	**Onset of reaction**
24°C	50%	4 years
21°C	50%	5 years
18°C	50%	7 years
13°C	50%	15 years
5°C	20 - 30%	150 years

4.3.1. Physical effects of vinegar syndrome degradation

4.3.1.1. Brittleness

At advanced stages of deterioration, brittleness increases to such an extent that the film can break with the slightest flexing. Severe brittleness cannot be reversed.

4.3.1.2. Shrinkage

Film can shrink for reasons other than degradation. Some small amount of shrinkage occurs over time through loss of solvent from the base, but really destructive shrinkage is a result of vinegar syndrome. Shrinkage greater than 1% is enough to cause problems for projection equipment. The capability of a modern telecine to handle shrinkage will depend on the type of film transport mechanism. Capstan transports are expected to handle up to two percent; sprocket transports are expected to handle less. In advanced stages of vinegar syndrome deterioration, shrinkage can be as much as 10% [2]. Shrinkage cannot be permanently reversed.

4.3.1.3. Channelling

In a situation with extreme base shrinkage, the gelatine emulsion layer may separate from the base, causing the emulsion to buckle up. Archivists describe this as *channelling*. The effect is irreversible.

4.3.2. Detecting vinegar syndrome

The smell of vinegar is often taken to mean that vinegar syndrome is present and that the acid level may have reached the autocatalytic point indicating that serious degradation may be occurring. However the questions to be asked at this stage are:

- How far has the deterioration reached?

  First, a physical inspection of the film should be made to check for signs of physical degradation.

- What is the acid value?

There are two methods available for measuring acid:

1) The free-acidity method (the more sensitive and reliable method).
2) The pH measurement method (a more practical method).

4.3.3. *Free-acidity measurement*

The free-acidity method measures the total amount of acid present in the film base. Values from 0 to more than 10 can be expected. ANSI standard IT9.1 [7] specifies the method used for free acidity measurements.

Table 4.3
Some examples of acidity values

Free Acidity value	Film condition
0.05	Typical for fresh film
0.5	The autocatalytic point where the deterioration rate advances
5 - 10	Advanced deterioration stages with very strong smell, shrinkage, buckling and plasticiser excludation

4.3.4. *pH measurement*

Another method that can be used to check for vinegar syndrome is to measure the pH of the air close to the film. Values of pH from about 6 to 4 indicate acidity values from 0 to 1 in the film. Easy-to-use coloured detecting strips are available from several manufacturers [IPI, Dancan]. A colour change will appear if acid is present. A blue colour indicates an acid value down to zero and a yellow colour indicates an acid level of 1 or above. The colour changes from blue to yellow, which are often referred to as IPI levels from 1 to 3 [8], represents an acidity value range from 0 – 1. The acid sensor strips are placed close to the film inside the enclosure for a time specified by the individual manufacturer. The colder the storage condition the longer the time it takes. Indicators are also available that can be mounted inside the cans and be easily inspected externally. [Dancheck]

Table 4.4 shows the relation between pH and free-acid values and the indications on the sensor strips.

Table 4.4
Different methods for the measurement of acidity.

pH	Free-acid value	IPI level	IPI Colour	Dancheck Colour	Distinctive Smell
6 - 5	0	0	Blue	Blue	None
5 - 4	0.5	1	Cyan	Cyan	Weak
4.8 - 4.5	1	2	Green	Green	Weak
< 4.5	1 or more	3	Yellow	Yellow	Strong

The different levels of pH indicate the levels of acidity and the consequent degradation. pH level 4.6 is the critical point, which represents the autocatalytic point. When material smells strongly of vinegar, the acidity level is close to or beyond the autocatalytic point.

The condition at the different IPI levels:

IPI level 0 – 1 The material is close to the original condition and has a long usable lifetime.

IPI level 1 – 2 The material is somewhat degrading, but it has not yet reached the autocatalytic point. The material should be watched more closely but will still have a long usable lifetime if stored in cold and dry conditions.

IPI level 2 or more The material has passed the autocatalytic point and the degradation is accelerating. The material will dry out, become brittle and there will be excessive shrinkage. The material should be given high priority for duplication.

4.3.5. Recommended action procedures following the detection of vinegar syndrome

If vinegar syndrome is discovered in a film archive, then it is very likely that other material is infected as well. Several steps must then be considered to protect the infected material and the whole collection. In a broadcast archive situation, the necessary action taken will depend on how the archive vaults are built. In principle, storage vaults can be vented or non-vented. Most vaults have been built to store closed containers in a non-vented storage environment (*see Section 6.3.*).

Recommended action procedures for a non-vented storage situation:

1) Segregate the discovered material to avoid the spread of acid to other containers.
2) Widen the inspection range and evaluate the condition and possible damage to other material.
3) Replace rusty containers.
4) If the container contains both film and SEPMAG, both materials are likely to be infected. Separate the SEPMAG and prepare a copy on polyester-based film.
5) Store infected material in a room separated from the main vault. Ensure good air circulation and a negative air pressure to avoid acetic acid vapour entering neighbouring rooms The preferred room conditions are cold (near to +5ºC) and dry (down to 20% RH).
6) Leave the infected rolls on shelves after removing plastic bags and cans. This will allow the acid to escape without obstruction.
7) Depending on the programme content value and the expected usable lifetime, the material in question should come under the company preservation strategy plan and be given the appropriate priority for restoration, either on film or by transfer to a digital medium.
8) If the infected material is not the first to be discovered in a collection, there should already be a strategy in place on how to prevent the spread of acetic acid. If not, then the following points should be considered for further action:
   a) Plastic and metal containers will trap the acid inside the can and will increase the degradation rate. Use of plastic bags inside a can will trap the acid even more.
   b) Cardboard enclosures will allow the acid to escape from the container, if there is no plastic bag inside.
   c) Acetic acid that escapes from film material (and the container) will cause the material inside to have a less rapid degradation, but the acid leaving the enclosure will affect the content of other enclosures if it is allowed in. If ventilated containers are used for degrading film, the air in the vault area should be filtered to remove the pollutants generated.
   d) If there is no smell of vinegar in a vault area, there is probably a sufficient rate of air refresh in the air-conditioning system. If there is a smell of vinegar then the air should be sampled, using industrial hygiene detection pumps or tubes. The quantity of pollution indicated should be compared against the benchmark level that was approved when the facility was new. The filtering and/or refresh level of incoming air should be adjusted and verified to meet specifications. If vented film storage containers are used, the circulating air should be filtered with those filters necessary to remove the unwanted pollutants, i.e. with activated charcoal, zeolite, etc.

(See further information on storage vault conditions in *Section 8.12.* and on microenvironments in *Section 8.11.2.)*

4.3.6. Problems specific to magnetic sound film (SEPMAG)

SEPMAG film is a film base coated with a conventional magnetic coating of ferric oxide and it has been used for sound post-production in the film and television industry. Acetate base was used for over thirty years before polyester became an alternative in the 1970s. However, many users continued to use acetate-based SEPMAG for much longer. The acetate base suffers similar degradation to the picture film but with an additional problem, in that the ferric oxide coating on SEPMAG film acts as a catalyst in vinegar syndrome degradation. Hence acetate-based SEPMAG film has a higher rate of deterioration than acetate-based picture film.

Actively degrading SEPMAG also presents problems with the replay sound quality. The material dries out and become stiff. Storage conditions may also cause buckling. The effect is to reduce contact with the replay head, thus causing a loss of replay quality. This is a further argument, beside shrinkage, for protecting programme material by copying SEPMAG to a polyester based material.

Many broadcasters have stored SEPMAG film along with the picture film. SEPMAG film, whether on an acetate or polyester base, will act as a catalyst for the degradation of acetate-based picture film or sound material even if any polyester-based SEPMAG will not itself be affected.

SEPMAG film should not be stored in the same container as image material

To summarize:

- No separate magnetic materials (SEPMAG or audio tapes) on either acetate or polyester base should be stored in cans containing picture film.
- Actively degrading acetate SEPMAG material should be removed from the film cans and copied on to polyester-based SEPMAG.
- Polyester SEPMAG should be stored separately from film, if the film smells of vinegar.
- A polyester SEPMAG that smells of vinegar has picked up the smell from nearby film or, in some cases, the out-gassing which is emanating from the iron oxide magnetic coating, even when polyester was used as the film base. The acidity may or may not diffuse through winding of the film.

4.3.7. *Problems specific to films with magnetic striping (COMMAG)*

COMMAG film is an acetate-based picture film with a ferric oxide sound track, coated on a non-picture area of the film and was used extensively for 30 years as 16mm news film. The presence of ferric oxide will increase the deterioration rate. Cold and dry storage is the only way of reducing the rate of degradation.

4.4. Problems specific to polyester-based films

Polyester-base materials were introduced in the 1950s. They are inherently more stable than either nitrate or acetate-base materials.

Experience has shown it has good chemical stability and overall good physical performance. Although polyester base is also subject to chemical deterioration, tests have shown that it will last five to ten times longer than acetate [2].

Chapter 5
Film — physical properties and physical distortions

5.1. Mechanical properties

The following is a list of desirable properties for motion picture film:

Strength	(Tensile strength) A measure of the pulling or longitudinal stress that the film can withstand before breaking.
Toughness	A measure of the resistance to stress and stretch before breaking.
Tear strengh	Resistance to tearing in initiation and propagation.
Stiffness	Rigidity (within its overall flexibility).
Yield strength	A measure of the force the film can sustain before permanent deformation.

Dimensional stability and resistance to moisture among other qualities must supplement these inherent physical properties. Film emulsion swells during processing, shrinks during drying, and the emulsion and base continue to shrink at a decreasing rate throughout their life. These changes are greater for acetate-base films than for polyester-base films.

5.2. Physical deformation

Film can be damaged when pushed beyond its physical limitations, during storage and handling. Improper low or high storage humidity and high- or low-tension winding will cause different short-term or permanent departure from flatness.

Dimensional shift in the film can be temporary or permanent. Temporary changes are caused by changes in relative humidity and temperature. In acetate film, permanent shrinkage is caused by the loss of residual solvents and by the gradual elimination of chemical staining introduced during manufacture and processing. Polyester-based film has no residual solvents or plasticiser. The dimensional stability of polyester is due to biaxial orientation at manufacture and is also partly due to its lower susceptibility to moisture.

In ideal storage conditions, film is stable at temperature and humidity equilibrium. This means that there are no tensional forces between image layers and base. Changes in temperature and humidity will create physical stress that can cause dimensional differences. The stability of the storage conditions is therefore important. Stable temperature being most important whilst humidity changes are less critical since humidity equilibration is a slower process. The edges of the film in a roll are like input/output gateways for the exchange of moisture. Humidity changes will create tensions and buckling since the edges will be affected more than the interior of a roll of film.

5.2.1. Brittleness

Acetate film that has lost most of its moisture and solvent will become brittle. Brittle film cannot be restored to its original dimensions. Proper storage and rejuvenation can reduce the brittleness but only for a limited time. Polyester film is more resistant to brittleness.

5.2.2. *Shrinkage*

All film base materials will shrink over time. This is due to the loss of solvent. The drying-out process causes changes in the physical dimensions. Acetate-based material is known to shrink more than polyester film. The natural shrinkage is expected to be less than 1% over some years after processing. More exact values [9] are:

- Processed negative film is expected to have a potential lengthways shrinkage of about 0.2%, which is generally reached within the two first years.
- Release print material is expected to shrink by about 0.1 – 0.4%.
- Shrinkage of a polyester base is unlikely to exceed 0.004% [9].

Higher shrinkage than the above figures can occur over a longer period of time, depending on storage conditions and especially if vinegar syndrome is present. In advanced stages of this deterioration, shrinkage can be as much as 10% [2].

Shrinkage of more than 1% is enough to cause real trouble. Any equipment using sprockets – for example, viewing tables, projectors etc. – can permanently damage film which is suffering from shrinkage. Shrunken film becomes a problem when the perforations no longer fit on to equipment transport mechanisms. A typical indication that film perforations are being damaged is the "ticking" sound of sprocket teeth not registering correctly and expanding the perforation holes.

Different equipment have differing abilities to transport shrunken film (*see Table 5.1*). For projection and edit tables, film is expected to have less than 1% shrinkage. The ability of a telecine to handle shrinkage will depend on the transport mechanism. Modern telecines using capstan transports will handle up to 2% shrinkage on standard equipment. Telecines using sprocket transports can handle less.

Table 5.1
Typical values for the tolerance of equipment to shrunken film.

Equipment	Tolerance to shrunk film
Edit tables (std. equipped)	Less than 1%
Projectors	Less than 1%
Modern Telecines:	
• capstan transports	Up to 2%
• sprocket transports	Less than 1%
Continuous printers	Less than 1%
Optical printers	Specially made transports to handle excessive shrinkage
Sound followers:	
• capstan transport	Up to 2% (typically)
• sprocket transport	Less than 1%

Shrinkage of SEPMAG will cause transport problems and head contact problems in sound followers. These have similar transport problems to telecines. Capstan-based transports can handle shrinkage up to 2% whilst sprocket transports are not expected to handle more than 1%. There are however modified transport mechanisms and special head assemblies available from certain manufacturers that can handle excessively shrunken and physically deformed SEPMAG material.

Film printers can use continuous transports or intermittent transports, as is the case of step printers. Continuous printers have a limited ability to handle shrunken films whilst step printers can be specially equipped to handle shrunken film.

Great care should be taken when reusing active degrading material. Film shrinkage gauges are available to measure the shrinkage, so as to avoid perforation damage in transports. Special care should be taken when film segments with different shrinkages are spliced together.

5.2.3. Buckle

This occurs when the edges (along the length) of a film are shorter than the centre.

Temporary buckle is caused by the loss of moisture from the edges (emulsion and base) when the film is stored in very dry air for short periods.

Permanent buckle is caused by loss of solvent from the edge when the film is kept in very dry air for extended periods.

5.2.4. Curl

The departure from flatness caused by dimensional differences between the emulsion layer and the base.

5.2.5. Edge weave

Occurs when one or both of the edges (along the length) are longer than the centre. This is the opposite of buckle.

Temporary edge weave is a result of storage under moist conditions.

Permanent edge weave Occurs if a roll is wound under high tension or if one edge is stressed during film transport.

5.2.6. Twist

Is caused by loose winding of new prints, emulsion-in, under dry air conditions. If the film is wound emulsion-out under the same conditions, the undulations do not alternate from one edge to the other, but are directly opposite one another.

5.2.7. Channelling

Is when emulsion separates from the base due to extreme shrinkage of the base.

5.2.8. Spoking

Is a pattern, outward from the core at the centre, caused by loose winding of film that has considerable curl.

Temporary spoking disappears when the film is unwound

Permanent spoking is seen as twist when the film is unwound

5.2.9. Embossing

Is a permanent deformation that occurs when prints are projected with high-intensity lamps, without heat absorbers. The excessive heat expands the picture area, and the picture stands out in relief.

5.2.10. Ferrotyping

Describes a smooth and shiny blotch or series of blotches on the emulsion surface. It is caused by the action of heat and/or moisture with pressure. Sources can include: faulty drying cabinets on the processing machine, winding under excess moisture (high humidity conditions), or subjecting the wound roll to high heat either before or after processing. It has also been caused by certain bleach formulations used in colour processes.

5.2.11. Scratches

There are many types of scratches. These include intermittent scratching, continuous scratching (commonly known as tramlines), short fine scratches, transverse, longitudinal and so on. Scratches are caused by external objects coming into contact with the film, such as equipment components, or dirty and worn rollers in the film path. The unevenness that a scratch creates on the film causes refraction of the light projected through the film. The end result, when using print stock, is that a black line appears on a screen. A coloured scratch would indicate that the dye layers on the emulsion have been penetrated. When projected over a distance, the refracted light can cause considerable interference to the visual image.

Emulsion scratches are more delicate in nature and more difficult to correct, especially if they have penetrated the dye layers and effectively removed image content (*see Chapter 9*).

Base scratches are easier to treat because this side of the film has a greater capacity to respond to various film treatments *(see Chapter 10.2.5.).*

5.2.12. Perforation damage

The principal transport mechanisms used with film can place a strain on perforations for a variety of reasons. The strain can cause the edges of the perforation to tear sometimes resulting in extensive damage over lengths of the perforated edge. The damage may also intrude into the image or sound areas of the film. This problem is particularly prevalent on buckled, warped or shrunken film.

5.2.13. Cinching

This defect is caused when dirt has become embedded on the film surface and marks the film when the film layers slide in loosely-wound reels. The action of slipping and pulling tight a loosely-wound film traps the dirt and causes small cinch-type scratches on the film surface. It is common to find this fault at the head and tail of film reels.

5.3. Splices

Cement splices have always been used for post-production work on motion picture film. However, the final product – the print for presentation – comprises one or more rolls of film without splices.

This has not always been the case in broadcasting. When news, sport and magazine programme material has been shot on film, the original camera film has often been assembled and used directly for presentation. When transparent tape was introduced for splicing, this became the normal method for splicing the film material used in broadcasting.

5.3.1. Cement splices

Cement splices can only be made on acetate-based material. Traditionally, an overlay technique is used but a more modern butt-wedge technique is also available. Cement splices are still considered necessary for laboratory processes such as assembling negatives for printing. Butt-wedges will avoid the disturbing effects of overlays but they are not accepted in many motion picture facilities because of the inherent weakness and the danger of breakage in film transports. For 35mm film, the overlay principle is mostly used whilst the butt-wedges are more attractive for 16mm film because the area available for splicing is smaller and the technique will result in fewer image artefacts. The "A-B roll negative assembly checkerboard" technique can be used to avoid the effects of overlay splices and to render the splices invisible.

Cement splices are considered reliable and durable if properly made. Over time, however, cement splices tend to dry out. A dry splice is visible as a shiny area seen from the base side. The problem when repairing cement splices is the possible loss of picture frames and the consequent loss of sound synchronism with SEPMAG tracks.

5.3.2. Tape splices

Tape splicing is a quick and easy way of splicing film on acetate or polyester base. This splicing method was originally intended for editing the work copies. The major benefit is the possibility of changing a splice without losing frames. A tape splice is, however, not as durable as a cement splice; it was never intended for archival storage. Many broadcasters have adopted tape splices not only for editing work prints but also for assembling camera film for transmission. Reusing such material has become a serious problem because the splices dry out over time and can break up. It is therefore important to replace the old splices before the film is reused.

It is important to replace a tape splice before it reaches the point where the adhesive becomes too difficult to remove without damaging the image as well. The adhesive of a tape splice can also ooze onto adjacent layers. This effect is often increased during film cleaning due to swelling of the adhesive by the solvents.

When replacing tape splices, it is good practice to replace all splices in a reel and not just the worst of them. Manual removal of adhesive is a challenging process because the adhesive must be entirely removed both from the splices and the adjacent layers without visual remains.

5.3.3. Splicing equipment

Special splicing equipment is available for both overlay and butt-wedge cement splicing. Machines used for splicing are liable to damage the perforations of shrunken film. In extreme cases it is recommended that film suffering this problem be joined manually. Splicing equipment must be kept clean at all times. It is particularly critical that tape splicers have sharp and clean knives and perforation punches, to ensure there are no protruding edges which can affect the image steadiness when the film is running through a telecine.

5.3.4. Splicing polyester-based material

The splicing of polyester-based film is a problem because traditional cement splices cannot be used. A solid splice can be made using heat-fusion techniques, using dielectric heating, ultrasonic energy or radiant energy. However, these techniques cannot be used to splice polyester-based material to acetate-based material. There is also a risk of affecting the images in an image sequence. Tape splices can be used on polyester-based film but these are not considered suitable for film laboratory handling or archival purposes.

5.3.5. Further information on splicing

Further detailed information on splices is given in EBU Technical Information I28-1994 [10].

Chapter 6
Effects of storage conditions

6.1. Variables that affect degradation

The condition and the remaining usable lifetime of film material in storage is very much dependant on storage history. There are several variables that, over time, affect the rate of degradation of the image and the support. The result is basically determined by the condition of the material to be stored, the environmental storage condition and the chosen strategy of enclosing the material for storage.

6.2. Condition of film material

It is difficult to ascertain the condition and estimate the remaining useful life of old film because the history of storage and use is usually not known. There are several problems with old films. Two of the major concerns are dye fading and vinegar syndrome. Because most film collections are acetate-based, the vinegar syndrome is becoming increasingly important.

Dye fading is a result of changes over time to the organic substances forming the image. The dye stability depends on the type of film stock, when it was manufactured and its storage history. Storage at high temperature and humidity increases organic activity and affects the characteristics of the image component. Checking the condition of the dyes entails evaluating or measuring the dye losses and the possible damage to the emulsion from the storage history *(see Chapter 3.2.)*.

Unlike the emulsion, the support material used for acetate-based films has not changed over the years. The same formula is still used. Since base decomposition becomes the dominant factor in ageing, the base acidity will give some idea of the remaining useful life of old film and its accompanying magnetic material. The colour dyes change at a constant rate, whereas the vinegar syndrome develops in a non-linear fashion. The acidity changes slowly until a certain acidity value has been reached. At this point, the degradation rate becomes more rapid *(see Figure 4.1)* and the level of vinegar syndrome then determines the remaining useful life of the film. This level is measured by checking the amount of acetic acid, for which several methods are available (*see Section 4.3.*).

6.3. Enclosure strategies

Acetic acid, released from decomposition of the base material, will act as a catalyst. It should therefore not be allowed to reach other material or build up inside a container where its increasing concentration will accelerate the degradation. There are two schools of thought on how best to deal with this problem. Either the decomposing material can be sealed in the storage enclosure or the material can be vented. In practical terms, this means that either the material is kept in a can, perhaps inside a plastic bag, or the acid is allowed to escape, either by storing the material without an enclosure or by using vented cans or card boxes without using plastic bags. Trapping the acid is not good for the affected film since it increases the chemical reaction due to its catalytic action. Venting may lead to other material being affected unless the atmosphere is controlled by sufficient air refresh rates or acid filtering or both.

Recent research by the independent Image Permanence Institute, Rochester NY, shows that venting reduces chemical reaction but increases shrinkage. Overall, the vented strategy seems to be the better option for main vault areas, but only on the condition that any diffused acid is not allowed to reach other film material. The design and capacity of the air-conditioning plant must therefore be based on which of the above options is used.

Non-vented storage has been the traditional option and is more common. Indeed it is the norm. Non-vented storage is still an option for any seriously endangered material that has been separated out, provided the other precautions are taken (*see Chapter 8.11.)*.

6.4. Volatiles in the film vault atmosphere

An important aspect of the design of a storage environment for film is detecting and managing the volatile substances that may originate from the film material itself. These arise from three main sources:

- Residual casting solvents and other material introduced during manufacture.
- Residual cleaning solvents used on processed film. This may result if the cleaning solvent used has absorbed water from cleaned film beyond its limit; or may be due to insufficient drying (e.g. when using percholoroethylene in a cleaning machine designed for 1,1,1, trichloroethane; when the ultrasonic cleaning machine ran too fast, or its vacuum was not working properly).

Table 6.1
Volatile substances possibly found in film storage areas.

Substance	Source
Solvents used in manufacturing:	
• Methylene chloride	Acetate film
• Acetone	Acetate film
• N-Butanol	Acetate film
• Cyclohexane	Acetate film
Cleaning solvents:	
• 1,1,1, trichloroethane	All film
• Perchloroethylene	All film
• Alcohol	All film
• Hydrofluoroethers	All film
• Isopropanol	All film
• Isobutylbenzene	All film
Volatiles from degrading film:	
• Acetic acid	Acetate film
• Butyric acid	Acetate film
• Nitrogen dioxide	Nitrate film
Volatiles from industrial pollution:	
• Sulphur dioxide	
• Hydrogen sulphide	
• Nitrogen oxides	
• Ozone	
• Peroxides	
• Free radicals	

- Volatile products of film degradation, such as acetic acid (from decomposing acetate material) or nitrogen oxides (from decomposing nitrate film).

When film collections are stored in areas designed for human occupancy, the ventilation rates usually are sufficient to keep volatiles at very low levels. If, however, film material is stored in large quantities in specially-built vaults, then air purification systems and/or sufficient fresh air exchanges are necessary to ensure that volatiles do not build up too much.

Volatiles in the storage area can also come from materials used for sealing and surface coverings of ceilings, walls and floors. Even shelf constructions and substances used for surfaces might influence the vault atmosphere. Care should be taken to use only substances that are harmless to film material.

Several companies specialize in (i) purpose-built systems to monitor the storage vault atmosphere and/or (ii) filters to remove volatile substances.

6.5. Effect of enclosures

Various effects on film can be attributed to the type of enclosure used. All enclosures should be made of material free of harmful gases that may affect their content. The enclosure might be a plastic bag, a cardboard box or a can made of metal or plastic. The materials and methods of construction of some enclosures will allow the contents to breathe; others may or may not. The preferred solution will depend on which storage strategy is adopted (*see Section 8.11.*).

6.6. Micro-organisms

6.6.1. Micro-organisms in archives

Micro-organisms (bacteria and moulds) are present everywhere around us. They occur mostly in the soil and water. There are many in and on the bodies of other organisms and in the air, on the floor, on the walls, on the cans, also inside those cans, on the cores. Various forms of micro-organism exist and behave differently. These include:

- yeasts;
- fungi;
- mildews;
- bacteria.

6.6.2. Micro-organisms in film emulsions

The gelatine layer of film material is an extremely attractive environment for microscopic fungi mildews (micromycetes), bacteria and yeast cells. Both ***bacteria*** and ***yeast*** cells are, however, very sensitive to the silver content of black & white film materials and also quite sensitive to the colour-forming components of colour films. They do not, in fact, represent a real danger to film materials stored under the mild conditions found in Europe.

On the other hand, ***mildew*** spores and their vegetative forms are highly resistant to silver, as well as to the colour-forming components of colour films. Thus they represent the main danger to film materials in storage. Mildew can grow on or through the gelatine layer, in this way damaging the gelatine layer both mechanically and chemically (by their metabolites). To a smaller extent, mildew will even damage the base, particularly the edges of the film as well as around the sprocket holes. Temperature and relative humidity are both of great significance for the growth and development of mildews. The optimum temperature for the majority of mildews is between 26 and 28°C. There are, however, some species called thermophiles, whose optimum temperature lies around 50°C. On the other hand, there are psychrophilic mildews which have an optimum temperature around 0°C or even lower. But even common mildews are highly adaptable and they can form thermo- or psychro-tolerant variants. The development of mildew occurs at a relative humidity above 60 per cent.

6.6.3. Micro-organisms in the air

The air in the storage areas will contain both ***fungal*** and ***bacterial*** spores that come to rest on surfaces. Dust particles present in the air increase the danger of fungal attacks, since they absorb the fungal spores on to their surfaces, encourage condensation and thus introduce conditions that are conducive to fungal growth. The number of micro-organisms in the storage area can fluctuate between tens and hundreds per cubic metre and depends on:

- the state of the storage area;
- the flow of air within the storage area;
- the flow of air into the storage area from outside;
- movement of personnel within the storage area, and consequent air disturbances.

The incidence of micro-organisms on film cans is likely to be 1000 times higher than the airborne levels. The number of micro-organisms on the floor is practically the same as that on the cans. Wide variations of the numbers on the walls can be expected. The reason is the variety of dampness of the walls.

6.6.4. Minimizing the risk from micro-organisms

The danger of microbial attack on film materials stored in the depository can be minimized by:

- Maintaining the air in the storage area at constant low relative humidity of (below 60%) and low temperature (below 12°C), to reduce the possibility of spore germination and growth.
- Immediately removing any traces of humidity – which can result in mould formation – from the walls or any other surfaces in the storage area. In cold climates, cold exterior walls may not be sufficiently insulated, causing continuing condensation on the interior walls. Additional insulation may be needed.
- Reducing the air currents to prevent the influx of spores from outside.
- Limiting the movement of personnel within the storage area to a minimum, thus reducing the dispersal of spores.

However, it is impractical to eliminate spores from the surfaces of film cans, and from the walls and floors of the storage area, due to contamination from outside the archive caused by the frequent movement of films in and out of the vaults.

6.6.5. Disinfection

If micro-organisms or insects have spread into the vaults, a special disinfection or control process should be carried out. This should be done with the aid of companies specializing in this field.

Chapter 7
Handling and inspection routines

7.1. Working conditions

Ideally, film should be handled in a clean room environment. Attention should be paid to keeping humidity between 50% and 60% RH. Humidity below 50% RH may cause static problems and attract dirt. Humidity higher than 60% RH might cause the emulsion to become soft and sticky and may create a risk of mould growth. Film tends to have minimum curl near 50% RH, minimizing problems with winding quality. Film with a low moisture-content is likely to develop static charges. This will attract dust particles that can cause wear and tear.

Good ventilation is essential when handling degrading films. Due to the health threat from some of the chemicals used in film processing and the substances given off by degrading film, working conditions should comply with national health legislation.

Latex, polyethylene or nitride gloves should be worn whenever handling degrading film in bulk. Otherwise, clean cotton or nylon gloves should be worn (i.e. when inspecting or repairing the film).

7.2. Operator knowledge

The issue of knowledge is a complex one and can cover many aspects of film technology. It is recommended that, due to the permanent value of film material held in archive collections, only competently trained operatives should handle film for examination or reuse. The level of training and the criteria applied to assess their competency should be at the discretion of the organization. Many of the recommendations referred to in these procedures should assist with the design of any training procedures and programmes on the handling of film material.

7.3. Physical handling of film

Film should be regarded as (i) sensitive to physical handling and (ii) valuable and fragile, as is often the case with archival material. It is therefore extremely important that only professionals should handle film material. It is important that film material is touched on the edges and margins and not on the image or sound areas.

It is also recommended that clean, soft lint free cotton gloves be used when handling and examining film to avoid contaminants migrating to the film surface.

7.4. Winding for storage

For storage, it is extremely important to wind film evenly and squarely with sufficient tension to provide a smooth, tight roll without protruding edges. If the roll is not tight and smooth, it can suffer edge damage and scratches. If the roll is wound too tightly there is a risk of stressing the mechanical properties, resulting in changes of film flatness during storage.

For storage of actively degrading material in particular, it is important to have a firm but not too tight winding to allow the material to “breathe”.

In cold storage conditions (designed for long-term storage with low relative humidity conditions), the emulsion typically shrinks more than the base. The film should always be wound with the emulsion side “in”, to avoid stress to the emulsion.

Mechanical winding equipment should be of a constant torque design and the tension should be adjusted to be just high enough to achieve a tight, even, winding throughout the roll.

7.5. Cores

The cores used for storage should have a minimum diameter of 75 mm, should be waterproof and made of a material not affecting the film or SEPMAG. Recommended plastic materials are polyethylene or high-density polypropylene.

7.6. Splices

Cement and tape splices on archived material need to be checked. Cement splices are typically the stronger and more durable splices, but eventually the splice may break up. Repair of cement splices in picture film may be impossible without a loss of frames and the consequence loss of synchronism with the accompanying SEPMAG sound.

Tape splices are temporary in nature and are unreliable and not recommended for archive use. They dry out and break, leaving dried adhesive, which can be very difficult to remove before applying a new tape splice. Inspection should always be carried out before reuse (*see Section 5.3.*).

7.7. Static electricity

As film reels rotate, static electricity will build up and attract dust and dirt to the film, particularly in situations where there is low humidity. Static electrical charges can be reduced by working at 45 - 55% relative humidity, which enables the discharge of static charges generated during rewinding.

7.8. Film cleaning

Film cleaning can be performed with or without solvents.

7.8.1. Solvent cleaning

Solvent cleaning can be performed manually or in a cleaning machine. Cleaning solvents can be hazardous, flammable and toxic. Some of the solvents traditionally used in cleaning machines, such as 1,1,1-Trichloroethane, are now banned due to adverse effects on the environment. An alternative solvent now in use, Perchloroethylene, has less effect on the environment but is more toxic, less effective and takes twice as long to dry. Research is going on to find alternative liquids for use in solvent cleaning. A list of solvents which have been tested for film cleaning is given on the Kodak website. (*see Section 6.4.* and *Further Reading* on page 66).

7.8.2. Adverse effects of solvent cleaning

Some adverse effects of solvent cleaning to be aware of are:

- Solvent cleaning of material with tape splices will swell the adhesive at the edges and cause adhesive to be released on to the adjacent layers.
- Solvents might soften the tape-splice adhesive and cause the film to slide apart, particularly on single-side splices.
- COMMAG films must not be liquid-cleaned before the solvent has been checked on a short section of the material. If a brown colour appears, do not proceed because this indicates that the magnetic coating is dissolving. There is also the risk of solvent attacking the COMMAG adhesive that might cause the loosening of the COMMAG stripe.
- Solvent cleaning should comply with national health legislation. All safety directions must be closely followed. Adequate evacuation of contaminated air at the source – rather than of much larger volumes of surrounding air once it has mixed with room air – and ventilation should be provided. Prolonged or repeated skin contact must be avoided.

7.8.3. Film cleaning machines

Film cleaning machines are available based on different principles of operation. Ultrasonic cleaning is considered to be the best method. Film is passed through a heated solvent in a tank fitted with a transducer or vibrating mechanism, which agitates the film. This removes loose dirt and most embedded particles. Hot air jets subsequently dry the film. These blow most of the solvent off the film and evaporate the rest. Some machines have rotating buffers to remove excess fluid or really stubborn bits of dirt. Other machines use more direct contact cleaning without the use of ultrasonic agitation.

7.8.4. Non-solvent cleaning

A dry cleaning method, based on soft surface rollers called PTR (Particle Transfer Roller) is used increasingly. The roller surface picks up dirt, dust, hair and particles from the film. This method has a high cleaning efficiency, and the rollers can be reused after cleaning with soap and water. The simplicity of this method means that it can be used in most film operations, from film winding to telecine. There are several suppliers of PTR rollers, and mounting brackets are available for different types of film equipment.

7.9. Inspection and checking routines

Any archive needs to have a programme of regular inspections of its collection. If the storage conditions are consistent with the recommendations outlined in this document, an inspection every two years will probably be sufficient. However, if the limits are exceeded, an increased rate of inspection will need to be considered. Such inspection should include measurement of the acidity level and colour dye fading on the films, as well as the degree of film shrinkage and the condition of splices and perforations.

During inspections, the degradations below should be checked.

7.9.1. Physical damage

Any film material entering the archive for storage should be checked for its physical condition to ensure that the material is in good condition and needs no repair. Damage to look for, in particular, is on the edge and perforation areas of the film.

7.9.2. Shrinkage

Shrinkage is a natural process that happens to all film supports. Acetate-based supports are known to shrink more than polyester support materials. The amount of shrinkage that can be tolerated will depend on the equipment used for transporting the film and SEPMAG (*see Section 4.3.1.*). The major cause of excessive shrinkage is the drying out effect from vinegar syndrome in acetate-based supports. If there is any evidence of vinegar syndrome, the film material should be measured to assess the amount of shrinkage before reuse.

7.9.3. Vinegar syndrome

When a film container is opened, check for any smell of vinegar. If there is a vinegar-like (acetic acid) odour, then degradation of the film has begun. The material should be measured and further action should be taken according to the instructions given in *Chapter 4*.

If there is any sign of vinegar syndrome:

- widen the area of inspection immediately;
- segregate any film and SEPMAG which shows signs of degradation, and store them away from unaffected film material;
- if you want to save the film, inspect it immediately to evaluate the possible damage;
- See *Chapter 4* and *Section 4.3.5.* for further action;
- See *Chapter 8* for future storage recommendations.

7.9.4. Dye fading

Dye fading can be tolerated in archival films up to a certain extent, depending on how the film is going to be reused. For broadcasters interested in reusing the film for television productions, the amount of fading that can be corrected will depend on the telecine equipment in use. To some degree, trained personnel can judge the fading by a visual inspection of positive images on print or reversal stocks. However, dye fading of negative images is more complicated to detect (*see Sections 3.2. and 10.2.4.*).

7.9.5. Physical deformation

Archival material should be checked for brittleness and curling. There are different causes of film departing from flatness *(see Chapter 5)*.

7.9.6. Fungus and mould

If the material shows signs of fungal growth or tackiness, then the storage conditions are outside safe tolerances. At the first sign of tackiness the material must be thoroughly cleaned to remove all surface fungi. This cleaning should be carried out with considerable care, as live moulds are dangerous to health *(see Section 6.6.)*.

7.10. Chemicals remaining from processing

Film material should be properly fixed and washed during processing. If in doubt, test for residual chemicals such as thiosulphate, trithionate, and tetrathionate. The "methylene blue" test gives a positive indication by a change of colour. This method is given in ISO 18917 [5]. It has the advantage that it can be successively performed any time after processing. Limits for residual thiosulphate are listed in ISO 10602 [11]. Any chemicals remaining from the processing should be removed by further washing.

7.11. Preparing film material for storage

The following general procedure is recommended before film is sent to storage:

- The material should be thoroughly clean.
- All material should have an even, low-tension, flat winding.
- Film should be wound emulsion-side “in”, to minimize stress.
- The minimum diameter of the core should be 75mm.
- Film and accompanying SEPMAG should be stored in separate containers.
- Material that is smelling of vinegar should be segregated *(see Section 4.3.5.)*. If the material is actively degrading then action should be taken according to company strategy.
- Storage containers should be in accordance with the storage strategies outlined in *Section 8.11*.
- Plastic bags should not be used inside containers intended for vented storage
- Film should be acclimatised before entering or leaving a cold storage vault. 24 hours is considered a sufficient period for most material *(see Section 8.13.4.)*.

7.12. Inspection of archive film before reuse

The following general procedure is recommended before archive material is reused:

- Look for rust, fungus and mould, and deposits on the material.
- Smell for the vinegar-like odour associated with vinegar syndrome.
- Check for shrinkage.
- Inspect splices for possible repair.
- Ensure there is sufficient leader and undamaged spacing material on the head and tail of the film.
- Fill out the technical status form *(see the example on page 28)*.

7.13. Inspection of archive film before return to storage

The following general procedure is recommended before archival material is returned to storage:

- Check for physical damage.
- Look for damage and rusty containers.
- Smell for the vinegar-like odour associated with the vinegar syndrome.
- Check for proper winding (i.e. low tension and the wind has no protruding edges).
- Check that proper cores are used, (min. 75 mm diameter, made of polyethylene or polypropylene).
- Check that film and SEPMAG are prepared for storage in separate containers.
- Check that the correct containers are used for vented or non-vented storage.
- Check that no plastic bags are used inside containers for vented storage.
- Ensure an acclimatisation period of 24 hours before return to the main vault.

Typical Technical Status Form

Archive can code:	
Programme title:	

Transmission date:		**Duration *(25 f/s)*:**	**h m s**

Prod. no.:		**Colour :** ❒ **B & W :** ❒
Prod. year:		**Transmission aspect ratio:** 4:3 ❒ 16:9 ❒

Complete programme: ❒	**Information about splices**	
Segments : ❒	**No. of splices:**	**Cement:** ❒ **Tape:** ❒

Information about the image film			**Information about the SEPMAG**			
Acetate ❒	**Polyester** ❒		**Acetate** ❒	**Polyester** ❒		
35mm ❒	**S.35mm** ❒	**16mm** ❒	**S.16mm** ❒	**16mm** ❒	**17.5mm** ❒	**35mm** ❒

Type of film material		**Used for**	
❒	Cut/spliced/camera neg	❒	Printing one roll (film)
❒	Cut/spliced/camera reversal	❒	Printing a/b (16mm film)
❒	Unspliced neg.	❒	Telecine grading one roll
❒	Unspliced reversal	❒	Telecine grading a/b
❒	Work print	❒	Telecine transmission direct
❒	Graded show print	❒	Telecine manual transmission
❒	Ungraded show print	❒	Optical projection
❒	Interneg (from print)		
❒	Intermediate pos/neg		

Physical condition										
Initials / Date	**Vinegar syndrome**				**Shrinkage**	**Curl**	**Tape splices replaced?**		**Scratch rating *(scale of 1 - 3)***	
	0	**1**	**2**	**3**	**(%)**		**Yes**	**No**	**Base**	**Emulsion**

Chapter 8
Recommendations for the storage of film

Information on storage conditions of fresh (unexposed) and processed film can be found in a number of international standards and recommendations. References to these documents are listed in the bibliography [12][13][14].

The present document and EBU Recommendation R101 [3] follow the same basic principles of proper storage. However, they also take into account the specific requirements of broadcasters to store and reuse film from their archives, whether in good condition or degrading.

8.1. Terms of storage

International standards and recommendations list two levels of storage conditions for different usable lifetime expectations:

1) **Medium-term** storage conditions – conditions suitable for at least 10 years.
2) **Extended or long-term** storage conditions – conditions suitable for material having permanent value.

8.2. Specific storage conditions suitable for broadcasters

In the early days of television, broadcasters had to choose between storing their films according to recommendations for medium-term or long-term storage. For many broadcasters, immediate access to the film was necessary and thus medium-term storage was most convenient and considered sufficient at the time. These conditions were intended for storage up to 10 years. 30 years later, broadcasters who are still storing film under these conditions will most likely have experienced serious deterioration in their film collections.

It will be very difficult to reuse any actively degrading material in the future if nothing is done now. Broadcasters should check their film archives and decide on the options to improve the storage conditions.

Doing nothing is not an option in this situation

Specific advice and guidance for broadcasters are given on the following pages.

8.3. General recommendations

The simple message on storage conditions for processed film and accompanying sound is:

- Relative Humidity below 20% RH must be avoided to prevent permanent damage from brittleness.
- Relative Humidity up to 50% RH will cause a more rapid development of vinegar syndrome and dye fading, and shorten its life expectancy, but otherwise will not harm the film.

- Relative Humidity above 60% RH, for prolonged periods, will encourage fungal growth in the gelatine layer.
- Gaseous contaminants such as sulphur dioxide, ozone, free radicals, peroxides, hydrogen sulphide, nitrogen oxides and solvents can cause degradation of emulsion and base *(see Section 6.4.)*.
- Stored film and magnetic materials react more quickly to variations in temperature than to variations in humidity.
- The oxide layer of magnetic sound material acts as a catalyst for vinegar syndrome. This is known to increase the degradation rate and affect the neighbouring material.

8.4. Specific recommendations

An archive collection will contain categories of material ranging from fresh film to endangered old material. The different categories can be stored under different conditions to meet the desired usable life. For the "actively degrading" category, showing vinegar syndrome, it will be important to establish cold storage conditions to slow down the chemical reaction. On the other hand, more recent fresh film may be less demanding on temperature, depending on the required life expectancy in years and the combination of temperature and relative humidity chosen to meet this objective.

The individual broadcaster will have to decide whether to establish different storage conditions for the different categories or to choose one condition for the whole collection. This is a decision very much related to the individual situation and the size of the archival collection.

The values listed in *Table 8.1* are considered practical lower values for storage conditions, to be aimed at for actively degrading film. Experience in complexity and cost of installation, and the operational consequences, for reuse are taken into account. Deteriorated film with permanent value must, however always be considered as an object for restoration and should be stored in colder storage conditions.

Table 8.1
Recommended storage conditions for acetate- and polyester-based motion picture film and magnetic sound.

Layer (image or sound)	Base	Temperature	Temperature stability	Humidity	Humidity Stability
Silver	Acetate	+5°C	± 1°C	25 - 30%RH	±5%RH
Silver	Polyester				
Colour	Acetate				
Colour	Polyester				
Iron oxide	Acetate				
Iron oxide	Polyester				

Notes to Table 8.1.

1) In general, each ~6°C of higher temperature will halve the usable lifetime and each ~6°C of lower temperature will double the lifetime.
2) Increasing the Relative Humidity from 25% to 50% RH will typically reduce the usable lifetime by a factor of two.
3) Film and magnetic sound on triacetate base, which smells of vinegar, is affected by vinegar syndrome and will deteriorate at a more rapid rate.

4) Film and accompanying magnetic film stored under these conditions should have an acclimatisation (staging) period in and out of the vault to avoid condensation. The time needed will depend on the film gauge and the size of the roll. 24 hours is considered sufficient *(see Section 8.13.4.)*.

8.5. Usable lifetime of fresh film

Raw stock manufacturers give information on the useful life of different film stocks. The emphasis has been on emulsion deterioration, the dominant factors being silver and colour dye fading. Recently, more attention has been paid to base deterioration since acetate film base shows serious degradation when stored at higher temperature / humidity conditions. Fresh film stored under the conditions recommended in *Table 8.1* will take many years to reach an acidity value of 0.5 (*see Table 4.1*).

8.6. Usable lifetime of archive material

It is difficult to predict the usable lifetime for archive film material in storage. The extent of image fading and base degradation will depend on the type of film stock, its age and storage history. Vinegar syndrome is nowadays considered the most critical risk for acetate-based film and SEPMAG materials. *(See Section 4.3.5. for tools to detect the condition and the recommended procedures to follow.)*

However, the usable lifetime of film material also depends on how it is to be used. There are criteria to predict the remaining usable lifetime in a film environment but the criteria may be different for a television environment. It is important for broadcasters to be aware of the “bottlenecks” in their own production system that may be the limiting factors for the usable lifetime of their archive material. For example, electronic methods can correct image fading beyond the normal capabilities of traditional film grading, whilst telecines and sound followers may have problems in handling excessive shrinkage.

8.7. LE (life expectancy)

The term “life expectancy” is used in ISO 5466 [12] and SMPTE RP 131 [13] as a prediction of the lifetime that can be expected for films in storage. At present, the definition of the term is unclear and its criteria and application is often open to different interpretations. The present definition given in SMPTE RP 131 is:

- The length of time that information is predicted to be acceptable in a system at 21ºC and 50% RH.

8.8. Time out of storage

It is important to be aware of the detrimental effect on the lifetime of archive material when it is kept outside the recommended controlled conditions. This is illustrated in Table 8.2, which shows how the time to reach a given level of acidity is reduced if the film is taken out of the vault and kept at normal room conditions for some days.

Table 8.2
Effects of “time out of storage” on the acid reaction rate.

Vault storage conditions	Days per year out of storage at 21°C / 60% RH	Time in years to reach 0.5 acidity
4°C / 20% RH	0	800
4°C / 20% RH	10	400
4°C / 20% RH	120	60

8.9. Relative humidity

The effect of temperature on the moisture content of air must always be taken into account.

The ability of air to carry water vapour varies with temperature *(see Fig. 8.1)*. At high temperatures, air can carry more water vapour than at low temperatures, before reaching saturation. Dew point is the term for the situation where air is saturated with moisture *(see Fig. 8.1 and Table 8.3)*. At any particular temperature, the ***relative humidity*** value is the percentage measure of the maximum amount of moisture that the air can hold at that temperature. If the air is carrying half its capacity, its RH is 50%. Absolute humidity is the weight of water vapour per unit volume of air.

Table 8.3
Temperature and humidity conditions.

Temperature/humidity	Dew point (100%RH)
20°C/80%RH	+16°C
20°C/50%RH	+9°C
15°C/50%RH	+5°C
15°C/30%RH	-2°C

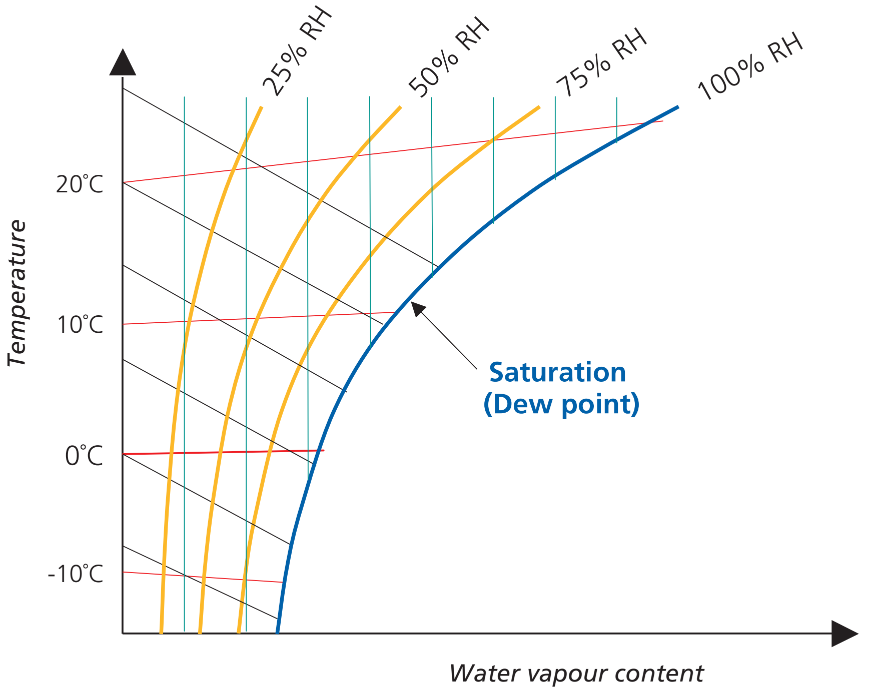

Figure 8.1
The Mollier diagram.

Figure 8.1 is the so-called Mollier diagram, which shows the relationship between water vapour content and temperature, at several different values of relative humidity. The curves show that the relative humidity will increase if the temperature of the air is suddenly lowered.

Relative humidity is always a factor in film storage, but it becomes especially troublesome at high temperatures because hot air can carry much more moisture than cold air. Therefore, film is more susceptible to changes in temperature at high temperatures, because the relative humidity will increase and there is the consequent risk of attack from moisture.

8.10. Moisture and temperature equilibration

Equilibration is the process of adapting to different environmental conditions. When storage conditions change, or when film is brought out of storage, the film does not instantly adapt to the new situation. The time needed to reach equilibrium depends on the film gauge and the size of the film roll. Temperature equilibration happens quite quickly. Even large rolls of film reach a new temperature within hours. Moisture equilibration, however, is a slower process which can take days, weeks or even months to complete. During the equilibration process, there will be unequal tension within the layers of the film. Since different layers have different equilibration characteristics there is a risk of temporary or permanent physical distortion.

Temperature stability is therefore considered more critical than humidity stability.

8.11. Storage strategies

There are many questions to be answered when deciding on a storage strategy:

- the size of the collection;
- the history and condition of the archive material;
- the expected usable lifetime;
- the established preservation programme.

When deciding on a storage strategy, policies on storage and enclosures – along with capital and operating costs – need to be taken into account.

8.11.1. Storage climate

Individual broadcasters will have to consider several criteria in deciding the climatic conditions for the storage vault. Having checked the condition of the collection, decided on the expected usable lifetime and established a preservation programme for endangered material, the question of storage climate can be addressed. If it is decided to set up a cold storage vault, the construction of the building and the design and capacity of an air-conditioning plant must be considered, based on the decision to uses either vented or non-vented enclosures.

If vinegar syndrome must be taken into account, a decision should be taken on a strategy to use vented containers or non-vented containers. Research by IPI [15] shows that non-vented containers trap acetic acid, which increases the catalytic effect and further speeds up the degradation rate. With the vented option, however, the same research shows that the degradation rate decreases inside the container, but an unwanted side-effect of allowing the acid to escape is that it could enter other containers. It is possible to increase the air refresh rate to avoid this, but this is generally not realistic since it affects the cost of the air-conditioning plant. The alternative solution is to install specially designed filters to remove the acid from the atmosphere.

The design and capacity of an air-conditioning plant must be based on the above demands. Traditionally, non-vented storage has been more commonly used. Indeed it is the norm. Experience and research on vinegar syndrome, however, indicates that vented storage may be the better choice for a main vault area. Non-vented storage may still be the best option for the storage of seriously endangered material.

8.11.2. Microenvironment

The inside of an ordinary closed or sealed can or bag will have a microenvironment climate. The idea of a microenvironment is to isolate the conditions inside the can from the general environment. A known method of microenvironment storage is the FICA method where the material is stored in a vacuum-sealed bag. Using plastic bags inside cans will of course contribute to further acid trapping. This is a problem if the contents already suffer from vinegar syndrome.

The use of a microenvironment is only recommended when it is not possible to prevent high humidity in the storage area. The internal conditions can be pre-conditioned. Absorbents can also be included. Research has shown that the benefits of microenvironments using absorbents do not equal those obtained by lowering the temperature and humidity of the storage area [15].

8.11.3. Storage containers

Various types of container can be considered, based on the strategy:

- plastic cans made of polypropylene or polyethylene – for vented or non-vented storage;
- sealed enclosures – sealed cans or plastic bags for non-vented isolation;
- cardboard boxes – for vented storage.

Film enclosures should be made of a type of material that does not contribute to any chemical reaction within the enclosure. Cans of un-coated iron or steel should be avoided. Tin-plated and coated metal cans are widely used but there is a risk of rust if the surface coat is broken. Plastic containers are an alternative. High-density polyethylene and polypropylene seem to be the best choices.

The main problem with enclosures is the accumulation of harmful gases or acid or rust that can build up and be almost completely trapped inside a metal or plastic can. If the lids are not closed the acid can escape. Plastic cans are available which are vented either through the lid or through punched holes in the sides of the can. Metal cans can be made vented by punching holes in the sides.

The properties of cardboard boxes are different from metal or plastic cans. Acid and gas will diffuse through the box material. This will be an advantage or a disadvantage, depending on the chosen storage strategy.

The cardboard material must be free from harmful residual chemicals (ANSI IT9.1 [7] or ISO 18917 [5]. Cardboard made of wood pulp is likely to contain lignin *(see Section 8.11.5.)*.

8.11.4. The use of plastic bags

Plastic bags are often used to separate the rolls inside a can or to hold paper information stored with the rolls of film or SEPMAG. It should be noted that these plastic bags could contribute to the trapping of acid inside a can. The advantage or disadvantage of this practice depends on the chosen storage strategy. Plastic bags shall be made of Polyethylene or Polypropylene.

8.11.5. The use of paper

Any paper stored with film material should be acid free and not have any effect on the content of a can. Specifications to be met are given in ISO 10214 [16] and ANSI IT9.2 [17].

8.11.6. Acid absorbents or scavengers

Acid absorbents or "scavengers" are available for use in enclosed microenvironments. Recent studies with film in sealed containers [15] show that adding silica gel or zeolite, commonly called a "Molecular Sieve" will reduce the moisture content and absorb acetic acid. This method works well with fresh film but has a very limited effect on material already affected by acetic acid degradation. Research further shows that the only effective way of reducing acid reaction rates is to lower the temperature and humidity in the storage area.

8.11.7. Acid indicators

Acetic acid indicators are available for insertion in film cans. These have similar properties to the so-called acid strips available from several manufacturers. These indicators help when combating "trapped acid". A typical indicator will show a colour change from blue to yellow between acidity values from 0 to 1 *(see Section 4.3.4.)*.

8.11.8. 16mm film and SEPMAG stored in 35mm containers

Many broadcasters have a tradition of storing 16mm film and SEPMAG in the same 35 mm can. With the experience of vinegar syndrome in old material, this practice has become a problem. The oxide layer on SEPMAG typically develops the vinegar syndrome twice as fast as film. The oxide acts as a catalyst and should not be stored with the film. Even when the SEPMAG is copied to a polyester base it should not be stored with film because of the catalytic effect of the oxide layer.

8.12. Design and management of cold storage conditions

8.12.1. Choosing a storage strategy

When a storage vault for cold storage is built or improved, the desired storage conditions need to take account of the following:

- the past storage history;
- the size and content of the collection;
- the amount of endangered film;
- the level of protection required.

8.12.2. Storage rooms

In a cold storage operation, separated areas are needed:

- main storage vault;
- isolation areas for films showing signs of vinegar syndrome;
- acclimatisation area for material going into and out of the main storage vault.

Storage rooms are sensitive to outside conditions. The rooms must be built to freezing-room standards and be well insulated, airtight and moisture sealed. There should always be a positive air pressure inside to protect from outside conditions. Any possible gaps between rooms or to the outside caused by cables, tubes or ducts should be properly sealed. Any doors and passages in the main vault need to be built for a minimum of leakage in use.

The storage vault should be built according to national fire protection regulations. Safety film does not represent a fire hazard but sprinkler systems may be required for insurance reasons or by law. Non-flammable surfaces are preferred for cabinets and shelves. Shelf construction should allow for proper air circulation to secure uniform temperature and humidity conditions for all containers. This is very important for solutions using modular shelves.

Building materials used should not emit any harmful gas that could affect the air cleanliness and the stored material. The floors should be of hard material that does not release dust. They should be abrasion-resistant and antistatic. They should be easy to clean and hard wearing. Floors should be level and not interrupted by stairs, thresholds, or doormats. They should not be made of materials releasing substances that would have a negative effect on the condition of the film material. They should be without any cracks and chinks, which also is a good precaution against insects. Similar considerations should apply to all interior surfaces of the building.

8.12.3. Environment and air-conditioning

An air-conditioning installation must be built to protect the contents from possible air pollution from the stored material and industrial air pollutants listed in *Table 6.1*. The air ducts and filters should be checked regularly, including checks of the filters for micro-organisms. It is advisable to take precautions against possible rusting of the air circulation equipment, caused by contact with acetic acid. Such damage has been reported.

Mechanical filters, preferably HEPA (High Efficiency Particulate Air) filters, should be used to remove solid particles, which may abrade the film or react with the image layer.

8.12.4. Refresh rate

Air refresh rate is an important parameter of an air-conditioning system. The air refresh rate depends on decisions taken relating to storage strategies and practical cost implications. Local weather conditions and/or air pollution might make it difficult to use a high refresh rate. In a cold storage vault with no sign of vinegar syndrome, the air refresh rate can be reduced to the amount determined by national health regulations. In a vault containing degraded material, it is important to remove acetic acid vapour. This can be done with an increased refresh rate from outside or with appropriate filters in the re-circulation path, or both. Using a high refresh rate to remove acid-loaded air is an unsound strategy that is also expensive in terms of energy use.

8.12.5. Stability of temperature and humidity

It is important to establish stability to maintain temperature and humidity equilibration. This prevents possible physical changes to the material. Stability of temperature is considered more critical since film material adapts more rapidly to changes in temperature than in humidity.

Stability of the conditions is considered more important than achieving low temperatures by overloading the air conditioning plant.

Target values for stability are:

Temperature: ± 1°C on an hourly basis;

Relative humidity: ± 5% RH on a daily basis.

8.13. Requirements of different environments

8.13.1. The main vault area

The target environmental requirements for the main vault are *(from Table 8.1)*:

Temperature: 5°C ± 1°C on an hourly basis;

Relative humidity: 25% ± 5 RH on a daily basis.

There must be a slight positive pressure to protect the vault from outside conditions.

8.13.2. Isolation area for actively-degrading film material

A separate area for actively-degrading film serves two functions: to isolate material that can affect other cans and to increase the protection of the degrading material. The air supply and circulation for the isolation area must be isolated from other storage rooms A separate air extraction and filtering system is necessary to remove acetic acid from material with vinegar syndrome. The air refresh rate will depend on the effectiveness of acid removal from the air circulation. The preferred environment for the isolation area is low temperature, to meet the life-expectancy targets for long-term storage of degraded film. The individual broadcaster will decide on the local situation and decide on strategies for long-term and short-term isolation of degrading film.

Inside the isolation area, the degrading material should be allowed to remain outside of containers and plastic bags. This is to allow the acetic acid to escape more readily.

Valuable programme material which is seriously degraded should however be immediately copied. The degraded material should be stored for protection at lower temperature. Possibly this could be in an enclosed microenvironment at a considerably lower temperature.

8.13.3. Condensation

When film is moved in and out of cold storage, there are risks of condensation. Since moisture will damage film it is important to avoid condensation on the film. Condensation is caused when air at high temperature becomes saturated with water when it is cooled to a temperature at or below its dew point *(see Section 8.9.)*.

When a film container enters cold conditions from ambient conditions, the air temperature inside the container is reduced and the relative humidity increases. Depending on the difference between the ambient and the cold conditions, there is a risk of condensation and moisture building up inside the container *(see Fig. 8.1 and Table 8.4)*.

Condensation may also happen when film is taken out of cold storage into a warmer area. The air in contact with the cold film container is cooled to below its dew point, resulting in condensation on the outside of the container. To avoid damage to the film material, it is important that it is kept inside the container in an acclimatisation area, until equilibration has been reached.

8.13.4. Acclimatisation area

The acclimatisation room should have an environment for conditioning material entering or leaving the main vault. Acclimatisation conditions should be selected to prevent condensation on material entering or leaving the main vault. The preferred temperature and humidity will depend on the vault condition and the outside condition. The climate must have a dew point that does not cause condensation on material coming out of the main vault. *Table 8.3* shows some examples of temperature/humidity situations and their related dew points.

The time needed for acclimatisation will depend on the gauge of the material, the size of the roll and the winding tightness. 24 hours is considered sufficient for most material.

The recommended environmental condition for acclimatisation of material stored at temperature 5°C and relative humidity 25%RH is:

Temperature: 15°C

Humidity: 30% RH

Table 8.4 shows the increase in relative humidity when moving a film can into colder conditions. It should be noted that some moisture would be absorbed by the film [15], depending on the winding hardness and the volume of film material.

Table 8.4
Moisture increase of air inside a film can when moved from warm to cold conditions.

FROM temp / hum:	TO cold storage at:	Moisture increases to:
20°C / 50% RH	10°C	Water
	5°C	Water
	0°C	Water
15°C / 30% RH	10°C	40%RH
	5°C	60%RH
	0°C	80%RH

8.13.5. Storage shelf construction

The shelves may be of fixed or modular construction. Containers should be stored horizontally. Any construction should be open and allow for air circulation. If steel is used, the surface should be coated with a material that is harmless to film material. Perforated shelves are preferred for securing good air circulation.

8.13.6. Storage room interiors

The inside surface materials used for ceilings, walls and floors should be treated with substances that do not emit volatiles that might affect film material.

Any sealing compound which is used should not contain acetic acid.

8.14. Storage below 0°C

Cold storage below 0°C is, in principle, good for film. However, the costs of building and air-conditioning such a vault are possibly prohibitive and would need careful consideration. Furthermore, the proper acclimatisation procedures – which are not always possible in a complex television operation – must be observed if the material is to be accessed without risk of damage.

In general, storage at temperatures below 0°C is not recommended for broadcasters.

Further information on storage-room construction is given in ISO 5466 [12].

Chapter 9
Film preservation

9.1. The value and remaining life of film in future broadcast archives

Film will continue to be the most future-proof material for the production of television programmes. The quality of film images is usually higher than that of present-day television systems. Film is durable and it will be accessible for several hundred years. There is little risk of film material becoming obsolescent, and the replay equipment is confidently expected to be available for any future television systems. But these benefits will only be available if existing film material is maintained in good condition. Experience shows that inappropriate storage conditions have caused and are causing degradation of both the film images and the film supports. It is therefore of the utmost importance to broadcasters to check the condition of their film collections and establish a preservation strategy.

Doing nothing is not an option when active degrading is discovered

Predicting the remaining usable lifetime of endangered material is often discussed on the basis of individual degradation variables such as image dye fading or base shrinkage. The film industry has established criteria for critical values of degradation but these may be different from the criteria that are valid for film material used in a broadcast production system. It therefore important for broadcasting organizations to be aware of the differences and to take the capabilities and limitations of their systems into account when considering the remaining usable lifetime for film material. (*See Section 8.6.)*

9.2. Film preservation programme

All broadcast organizations should consider their film collections in the light of possible serious active degradation. Any 30-year old collection is liable to contain actively-degrading film and sound material.

First of all a project should be set up to assess the state of the film collection. Vinegar syndrome is the key degrading variable to look for. A final status report should contain an evaluation of the usable life that can be expected from each item *(see Chapter 4)*. Depending on the results, the broadcaster will have to decide on further action. If the collection is in good condition and there is no evidence of critical degradation, then there is no need for alarm. However, if there is active base degradation that has reached critical values in any part of the collection, action must be taken. Resources must be provided to support a preservation strategy to safeguard and preserve endangered film material. In setting up such a strategy there are some basic issues to be evaluated:

- the condition of the archive collection;
- the usable physical lifetime of the material;
- the expected exploitable value of the programme content;
- the policies of the organization for different categories of endangered programmes;

- the available resources for film preservation.

This will allow priorities to be allocated to the programme material to be preserved.

Depending on the strategy and the resources available, a preservation plan can be set up and the activities decided in more detail. There are a great many internal, and possibly external, activities that need to be established and co-ordinated under a future-proof and cost-effective preservation strategy.

Although film material in good condition will give a usable lifetime of hundreds of years, endangered film might already be close to the end of its life, and thus needs to be preserved. The recommended best way of preserving endangered film is to copy the content onto another film material. There are however practical problems and cost issues that often make this option difficult to implement. Broadcasters also see that, in the future, film will be exploited as electronic signals. They often find that the digital electronic option is attractive from its cost-effectiveness in the short-term, and it opens up possibilities for exploitation and ease of management in the future. However, further migration strategies to cope with the obsolescence of video or recording technologies may require a more expensive infrastructure – to ensure the survival of the content – than if the material had simply been protected on film in the first place.

9.2.1. Film-to-film preservation

Preserving endangered film by copying its content to another film material is available where the actual programme is produced according to traditional film production methods. A graded film copy would then be the final product. Given a cut negative in a reasonably good condition, a new copy can be produced on polyester base. If, however, the film material has been used in an integrated film/video production method, the archive material may not be configured for film copying. There are certain rules that have to be followed in a copying process. Saving non-printed material by copying to another film is in principle possible, but there are conditions to be met that make this process difficult and expensive in practice.

9.2.2. Electronic preservation

There are reasons for transferring film to video beside the fact that film materials are endangered by fading and shrinkage. The physical nature of film makes it vulnerable to damage through usage. Much of broadcasters' collections consist of the original shot film only. There is the risk of damage through frequent reuse.

The disadvantage of preserving film as video is the possible loss of reuse flexibility for future production. This is because certain image parameters like scanning resolution and image aspect ratio must be configured for the system-defined production format to be recorded. This scene is getting rather complicated since there are current production standards for conventional resolution production and there are several proposed HDTV future production formats. Video production recording formats can be uncompressed or compressed. The component-uncompressed format is considered best for film preservation. Compressed formats are less transparent but are the current recording format being used by most broadcasters.

9.2.3. Transfer to a digital medium

Film is different. Whilst legacy videotapes may be digitized within the same timespan as the programme duration, film needs several operations in the transfer process:

- inspection;
- remedial action;
- grading;
- pre-programming;
- transfer.

This makes the transfer of film to a digital medium very labour intensive, time consuming and expensive.

Furthermore, broadcasters face a dilemma over which digital recording standard to use. If they take account of today's production requirements, they may possibly have to repeat the transfer for future needs. If they try to be future-proof and choose a higher resolution now, they may make a wrong choice. The choice very much depends on the current condition of the material, the predicted potential for reuse and the business needs of the organization. If the material is in a good condition there is always the possibility of making a later transfer. This may, however, not be the option for endangered material with a short usable lifetime.

Good storage of film keeps the options open

9.2.4. *The human factor*

A preservation programme is not possible without the necessary human skills to maintain and operate the equipment, much of which is about to become obsolete or forgotten. There is a danger that these professional skills and knowledge will fade away in a technology environment that is ever changing. Preservation and restoration of programmes depends on an understanding of how the programmes were made in the first place. The professionals should be given the opportunity to pass on their knowledge, experience and skills.

Chapter 10
Film restoration and treatment

10.1. General

Physical wear and tear, through use and storage, may cause damage and physical changes to film material. Different methods can be used to repair this, based on film or electronic techniques. Broadcasters are well placed to exploit electronic correction and concealment as well as traditional methods of film restoration. With current technology, the consequence of using electronic methods will normally limit the reuse of the material to current video standards but there is the possibility of making a new film copy from the video result. In reality, it is likely that a combination of methods will be used.

Nitrate film is not discussed in this respect.

10.1.1. Film-to-film restoration

It should always be remembered that when programme is shot and finished on film, the resultant film print enjoys the property of durability and is not restricted to any television system, now or at any time in the future. If the final film material, intermediate or print, is damaged or starts to degrade, the first choice should be to replace the damaged material by making new print material. However, the special production methods used for television, which use camera film directly, leave no printed material for archiving.

Film restoration covers chemical and physical methods that can treat, repair or replace damaged images or perforations. The images may need repair for a number of reasons: base or emulsion scratches, dye fading and shrinkage etc.

Not all film laboratories offer a film restoration service. Special techniques and equipment are required for restorative work on film. This is the case for film material suffering from dye fading where some improvements can be achieved by traditional grading techniques, but special techniques are necessary to correct for excessive dye fading. Normally, optical printers can handle shrunken film where the transport mechanisms are designed to handle different amounts of shrinkage.

10.1.2. Film-to-video restoration

Image manipulation and correction has always been a part of the telecine process. Manufacturers of telecines and associated processing equipment have continually improved their equipment over the years to enable them to transfer a higher quality from film. The equipment has also been improved to correct artefacts that are common within film technology. In many ways the modern telecine can be looked upon as a sophisticated electronic optical printer with the magic of concealing film artefacts such as scratches, dirt, noise, grain, dye fading and image instability.

The image correction process in a telecine includes the ability to correct for colour casts at different image levels. The red, green and blue primary colour signals captured from film are processed separately. There are normally corrections for colour balance at highlights, lowlights and medium level lights of the image. These allow colour-casts at different light levels to be corrected and allow the operator to aim for neutral reproduction of objects at different signal levels between black & white.

In an archive operation, perhaps the most appreciated facility is the ability to correct for image fading. The telecine has a wide range of correction functions that can deal not only with fading but also tracking errors. These sophisticated corrections for luminance and colour relations are not possible with film technology.

The ability of a telecine to handle shrunken film is dependent on its design principle.

In using electronic restoration as the alternative to film restoration, one has to be aware of the lost opportunity to preserve the film as film. Electronic concealment also leaves artefacts that are difficult or impossible to remove later. These perhaps could be avoided when more intelligent equipment is available in the future. Electronic restoration should therefore not be considered as a method of duplicating film material over the long-term.

After transferring the content of endangered film material, the film should be properly stored. This will ensure that it is still possible at a later date to transfer the content via a next-generation telecine – thereby benefiting from improved transfer quality and correction facilities, giving fewer artefacts – or to transfer the content to a different electronic medium such as HDTV.

10.1.3. Film to video to film

In addition to the options discussed above, it is possible to correct for degrading, damaged or faded film material by transferring the film images to video, correcting for artefacts and then transferring the images back to film. This process can be used with conventional-resolution television signals, but not without loss of quality from the film images. It is better to use a high-resolution telecine or scanner to transfer the images for subsequent signal processing, based on a high-definition video or data file. The corrected signal can then be transferred back to film with a quality close to the original film. This high-cost process is normally available to broadcasters as an external service.

10.2. The restoration process

It is recommended that five procedures be considered for restoration:

1) film examination;
2) film treatment;
3) film duplication;
4) telecine and electronic restoration;
5) quality control.

Film needs to be checked for physical damage, fading, scratching, dirt, etc. Tape splices or cement joins need to be inspected and, where mixed material has been assembled and spliced together, film geometry should be checked. It is recommended that a record be made of the examination so that historical data can be logged and referred to when the material is reused. This will assist in identifying the previous use of the film material in production and what previous work has been carried out on the film (*see the technical status form on page 28)*.

Typical faults, which need to be checked, are:

- shrinkage;
- image damage;
- perforation damage;
- dye fading;
- scratches and dirt on the base and emulsion.

On completion of the examination, an informed decision can be made concerning the corrective action to be taken for the restoration of the film: duplication, film treatment or telecine / electronic correction or reconstruction. It is recommended that the decision be recorded on a Technical Status Form *(see Page 28)*.

Furthermore, whatever plan of action is chosen to restore the film material, the issue of quality control should be of strategic importance. Quality control should be carried out to assess the results of any restoration or copying work. Restored and copied material may be considered for archive retention immediately or possibly following reuse. Whichever is the case, the quality of the product, after following any of the restoration processes described above, should be analyzed and documented.

Additionally, it is recommended that the original film be kept – despite any copies being produced – because the future may hold significant changes in technology, which may allow the original film to be reused more effectively.

10.2.1. Shrinkage

Any shrinkage greater than 1% is enough to cause problems for projectors and sprocket transports in edit tables and sound followers etc. In advanced stages of deterioration, shrinkage can be as much as 10% [2]. Shrinkage cannot be permanently reversed.

Shrinking can be reversed to some degree by placing the loosely-wound film, emulsion-side out, in a closed chamber containing a bath of a mixture of acetone, glycerol and water. The process can be accelerated if used in conjunction with a vacuum. This process improves the suppleness of the film and can assist with very brittle film, which otherwise cannot be wound without breaking the film. If this process is used, the treated material should be immediately copied because the de-shrinking effect is only temporary.

It is important that film that has suffered severe shrinkage is not run on projectors, or editing or viewing tables. The transport mechanisms of these tables have very little tolerance to cope with shrunken film *(see Table 5.1)*.

The most suitable procedure to deal with shrunken film is to reprint the material using an optical printer that is specially equipped for shrunken film.

Most telecines with modern capstan transports have a greater degree of tolerance than edit and viewing tables but this still may not be adequate to run shrunken film. Therefore, the potential to cause further damage to perforations and image area is enhanced if the level of shrinkage is not established before it is run.

The transfer of shrunk film using a telecine should only be considered after the shrinkage has been ascertained and is considered safe for the telecine in question *(see Section 5.2.)*.

10.2.2. Image damage

Sometimes, damaged or lost images on print material and/or the associated optical sound do not exist in the form of a cut camera material or intermediate film. This presents a problem of how to recreate the lost images. In a film laboratory it is possible to stretch scenes by multiple copying some of the frames. The results very much depend on the content and from which generation of film the lost images are taken.

In a video operation it is possible to stretch scenes without too much loss of quality but, as with film technology, stretching images with object movement is always a problem.

Another process is to digitally scan the damaged shot and multiply the frames by electronic interpolation then transfer the result back to film again.

There is a limited possibility to repair damaged film frames by hand but the degree of success that can be achieved depends on the level of damage. Only experts trained in the art of manual film restoration should carry out this form of restoration.

10.2.3. Perforation damage

Loss or damage to perforations can happen in any sprocket-based transport mechanism. In the case of a print, there is always the possibility of producing a new print. If, however, the material cannot be replaced by a new print, there is a major problem. Most film mechanisms rely on the perforations for transport. Although modern telecines may be based on capstan transports, they still rely on the perforations to capture the image.

The effect of perforation damage depends on the extent and nature of the damage. Remedial action will also depend on the extent and nature of the damage, and on whether repairs will be possible.

The film may be copied frame-by-frame but this is a very slow and difficult process and success depends on the extent of the damage. It may also be possible to get round the damage by running the film in reverse, particularly in the case where the film has perforations on both edges. If neither is possible, then the followings options may be used.

Polyester-based adhesive tape with perforations identical to those of film can be used to repair damaged perforations. This tape is resistant to solvents and makes a strong bond with film. This solution should be used only for small sections of damaged film and the tape should be applied to both sides of the film. It is important that the film is cleaned of dirt and dust before the tape is applied, to ensure that nothing is trapped under the tape. However, a tape repair cannot ensure that the images will be free from vertical unsteadiness.

Alternatively, it may be feasible to reconstitute the damaged film from another film copy, if one is available, either by splicing and replacing the damaged section from another print or by reprinting the damaged section from the original negative or intermediate. It must be borne in mind that if a section from another film print is joined using cement splices, a number of adjacent frames will be lost at each joining point. Therefore, the continuity of the film images should be carefully checked.

10.2.4. Colour-dye fading

Dye fading cannot be corrected by film treatment. A certain amount of fading is normally correctable in printing processes but correcting for fading beyond 30% in a film-to-film process is complex and uses specialized techniques *(see Section 3.2.)*.

An attractive alternative for broadcasters is to correct image fading in the electronic domain, where it is possible to handle complicated and severe fading in a controlled manner. The correction characteristics allow fading errors in individual dye layers to be tracked and corrected *(see Section 11.7.1.)*. But when the limits of electronic correction are reached, there are no other means of restoring the images.

If electronic correction is chosen, it should however not be forgotten that:

- the film material will no longer be suitable for optical projection;
- the fading will continue and there is a risk of losing the images when the material is revisited for another transfer;
- a request for another transfer, for future television reuse, is at risk.

If the faded film material only exists as a tape-spliced camera original, then telecine restoration is the recommended option for copying and restoring the images. In this situation it should be taken into account that there might not be another opportunity to transfer the material, since there is no material to make another film print. Therefore the decision regarding the preferred quality and the amount of correction to apply during electronic transfer should be considered in the knowledge that this may be the last opportunity to copy from the film before it is lost.

10.2.5. Base and emulsion, scratches and dirt

Dirt and scratches are of particular concern to original negative film and, to a lesser degree, to duplicates, intermediaries and prints.

Although, on occasions, scratches and dirt might not be considered causes for restoration (they may be part of the intended artistic interpretation e.g. to falsely age a film when projected.), this type of imperfection should generally be considered adverse to film use and should be corrected where possible. Various film and electronic treatments during printing or transfer can handle most defects but, at times, the effects are severe and call for restoration. A number of processes can be applied.

Emulsion scratches are delicate in nature and difficult to restore and correct. The visibility of these scratches will depend upon their depth and whether any dye has been lost. These areas of the film are the image-bearing layers and therefore extensive work will be involved to correct scratches. On a screen, emulsion scratches show up as coloured as opposed to simply black or white.

Base scratches are easier to correct and restore because the base of the film is more robust and can withstand the attention that film treatments can offer.

The first process in any treatment or restoration process is proper cleaning. Ultrasonic cleaning is considered the best way of removing dirt and grease pollutants etc. from film *(See Section 7.8.3.)*.

A treatment known as "re-washing" can be used to remove scratches (Kodak process RW-1). Suspending the film in an alkaline solution allows the scratched emulsion to swell. The sharpness of the scratch is thus softened and the film partially heals itself. This way, the scratch causes less refraction of light when being displayed. The problem with re-washing is that it can warp the film if the film is re-washed more than a couple of times. Secondly, and particularly with negatives, there can be a shift in the colour balance which requires correcting at a later stage.

In a video environment, equipment is available to conceal scratches that can be used in real-time or pre-programmed for subjective settings.

A method known as ***wet-gate printing*** is another option for concealing scratches and dirt in film. Any base side scratches are filled with a liquid during the printing process and the stripes are not transferred to a next generation of film. The wet-gate apparatus may be a separate applicator or a wet-gate printing head, where the film is immersed in liquid during exposure.

Glass wheel polishing and matting are other techniques used to repair more severe scratches on the base. In glass wheel polishing, the film is dipped into a small reservoir of acetone solution and is transported under tension over a highly polished rotating wheel. The acetone softens the cellulose triacetate base material and the scratches are filled with dissolved cellulose-triacetate from adjacent areas.

Matting can be carried out when the scratches are too severe for polishing to be effective. This process uses a wheel with a rough matt surface like ground glass to eliminate very deep scratches. Following this process the film base must be rendered smooth again by using a glass wheel and polishing. This is a risky process and should be considered carefully before use.

Glass wheel polishing cannot be used on the gelatine emulsion side as it relies on re-dissolving cellulose triacetate base with acetone. However, short lengths of emulsion can be polished by hand using a mildly abrasive metal polish. This is a risky procedure and should really only be used as a last resort, as sometimes it causes more damage than it cures.

In a telecine, base scratches can be concealed by:

- using a telecine with a diffuse light source or a light diffuser in the light path;
- using a wet gate to fill scratches in the same way as explained above for film copying.

Film duplication is the final option and probably the most complex area when considering the merits of restoration. Having examined the film, it may be decided to go back to an original camera negative, if there is one, and produce a new graded print. It may also be decided to use other generations than the camera negative, reversal or intermediate material – because of constraints of time, cost, production methods used and the type of telecine to be used.

Telecine work and the success of the transfer will largely depend on the type of stock – print, intermediate or camera original – used for the transfer.

In the duplicating stage, wet-gate printing can do much of the restoration work. That is, if the material is damaged on the base side and there is no damage to the emulsion.

The type of stock used for making a duplicate depends on the original final product and the artistic intentions expressed through contrast and colour reproduction. This could be a graded low contrast print or an intermediate material.

When duplication is necessary to preserve a programme shot and finished on film, film-to-film is the preferred route for programmes expected to have a long usable life for television.

Chapter 11
Converting motion picture film to electronic signals

Transferring images on film to electronic signals is a translation from one visual medium to another. Two different technologies come together, and the tool for transforming the images is the telecine. Film intended for optical viewing needs to be configured differently for television presentation. The differences in the two methods of image reproduction and presentation makes this conversion a rather complex process, which needs to be based on a scene-by-scene subjective evaluation and correction.

11.1. Reproducing film images on the television screen

Most of the film stocks used for television programmes are the same as those used in the motion picture industry. However, film projection and television display are obviously very different technologies, and linking film to television has been, and still is, a technical and operational challenge.

The basic problem is that the film prints made for projection in the cinema have a higher contrast than those preferred for television use. The reproduction of colours by a telecine has depended on design constraints, although this is less of a problem on modern designs. Film images from a telecine also need to be colour balanced to match the television system's colour balance value (6,500K). To give a pleasing continuity for television purposes, the images from films prepared for projection often need to be adjusted scene-by-scene for image contrast, gamma and colour reproduction.

To be able to handle all these possible aspects of using film for television, telecines are equipped with sophisticated image processing which is pre-programmable for corrections to individual scenes.

Traditional film production uses a number of different apertures and aspect ratios. To capture the desired image area, a telecine needs to be able to select a variety of image areas according to television presentation at either a 4:3 or 16:9 aspect ratio.

Film images often have artefacts such as scratches, dirt and grain that need concealing. Image steadiness might also need to be improved.

11.2. The telecine transfer operation

In a film image there are no replay reference signals for objective alignment. Telecine transfers are therefore largely based on operational procedures that rely on subjective assessment and evaluation. Common to all telecines are basic facilities to correct for film variations from scene to scene. These are variations of density, image contrast and colour tracking. Whilst some correction can be objectively applied with the help of instruments, the final image is the result of subjective assessment.

For example, balancing low and high image levels for neutral reproduction is easy with an oscilloscope, but it does not mean that the picture is acceptable (the film may have a colour cast). This is a typical situation for archival films that have poor colour dye tracking, due to dye fading.

11.3. The tools for subjective assessment

Good viewing conditions are crucial to make an accurate assessment of image quality. The picture monitor and the viewing conditions should meet current recommendations, otherwise the "corrected" images will not appear as intended.

11.3.1. The picture monitor

The variables to check on the picture monitor are:

- luminance level of peak white (80 - 100 cd/m²);
- luminance level of displayed black (1 - 2 cd/m²);
- colour balance (Illuminant D 6500K) adjusted with the help of reference neutral surround lighting or a reference light box;
- colour tracking (grey-scale reproduction);
- colour saturation (adjusted on a colour/bar signal);
- the entire active picture area should be displayed on the monitor (so-called under-scan).

The recommended specification for monitor alignment can be found in ITU-R Recommendations BT.814 [18] and BT.815 [19].

11.3.2. Viewing conditions

Visual adaptation is the phenomena where the viewer adapts to compensate for the colour of the surroundings. Therefore, subjective assessment should only be carried out on a picture monitor in appropriate viewing conditions. The picture monitor should have surrounding lighting that represents the television system colour balance (6,500K). This lighting serves two purposes:

- a subjective, neutral, visual reference to lock the adaptation of the operator's eyes;
- a reference neutral for matching any image neutral areas.

There are other tools used for neutral reference purposes, such as illuminated grey scales positioned close to the picture monitor. Operational lighting of a telecine control room should comply with the recognized standards for viewing conditions, given in ISO 12608 [20] and ITU-R BT 500 [21].

11.3.3. Future displays and subjective assessment

In the near future, the consumer will increasingly use larger screens (e.g. 42" – 50"), in particular flat-panel displays. There is some evidence that the size and quality of these displays will show up artefacts of film images, such as picture instability, graininess, lack of definition and motion judder, which are more or less acceptable on smaller displays. To take account of this, the visual quality should be assessed on similar larger displays during the transfer of film images to electronic signals.

11.4. Telecine handling of different film characteristics

There will be film material from many different categories of programme-making in a broadcaster's film archive. For news, sports and current affairs programmes, the only available material for transfer might be camera films. On the other hand, for documentaries and dramas produced using traditional film techniques, there may have been several generations of images on different film stocks.

Modern telecines are able to handle all the different film stocks used for shooting, post-production and presentation. Most of these film stocks are made to meet requirements in the traditional film production chain. The stock properties are different for shooting, post producing and presentation. Therefore each type of film to be transferred requires special telecine facilities and operational settings.

Some of the characteristics of film stocks that are important for telecine transfer are described below.

11.4.1. Density range

Each type of film stock has its own density range and contrast, depending on its intended function. A camera negative stock is a low-contrast stock, intermediate stocks for laboratory techniques have a somewhat higher contrast, while print stocks intended for projection have a contrast to meet the requirements of cinema projection. With a film stock designed for cinema projection, it has always been, and still is, difficult to produce pleasing images for television. The resulting effects can be high contrast images with burned-out highlights, shadows without details and high apparent colour saturation. If a lower contrast print is needed, then this is achieved by lowering the maximum density value and using special print stocks or by changing the processing conditions.

11.4.2. Colour dye tracking

A colour film stock will reproduce scene neutrals by maintaining the same relation between the colour dyes. Colour tracking is a critical issue for telecine transfer. This is a particular problem with archival material, due to differences in the fading of the different dyes over time. The dye values at different density levels no longer track and will cause colour casts. Various telecines and image correctors have sophisticated correction properties for handling tracking errors. The tracking can be expected to be best in a camera negative or intermediate stock, whilst reversal camera stocks and final print material intended for projection can often be a challenge for the telecine operator.

11.4.3. Image polarity

The image on camera and intermediate film stocks can be positive or negative. Telecine transfer of negative material is more critical because dust and dirt will appear as white “sparkles”. A clean machine environment with dust-removing PTR rollers (Particle Transfer Rollers) or wet-gate operation is necessary to secure optimum performance during negative transfer.

11.4.4. Image masking

Masking is a technique to correct for telecine spectral response and colour dye deficiencies in film stocks. The orange cast on negative film requires more blue and green light in a telecine to avoid electronic noise.

11.4.5. Tonal reproduction

The tonal reproduction in different film stocks will vary. Camera reversal and print stocks have a less straight-line tonal reproduction than negative and intermediate stocks. In a printing process there can be optical flare that also affects the tonal reproduction. Transfer from the original camera film will therefore gives less tonal distortion on the end result than transfer after multi-generation printing.

11.5. Categories of film stocks

From a telecine point of view, film stocks can be grouped into three categories:

- print stocks;

- intermediate stocks;
- camera original stocks.

11.5.1. Print stocks

A print intended for projection

This will have high densities in shadow areas and a contrast intended for viewing in a dark cinema. This will be difficult or impossible to handle depending on the film's individual lighting style and its scene-by-scene content.

A print prepared for use in television

If a print is made on a film stock designed specifically for telecine use, then it will have somewhat lower maximum densities and a lower contrast more suitable for television use.

11.5.2. Intermediate stocks

Intermediate film stocks are used in the film laboratory as the way to include optical effects or to produce many prints, often thousands, from one original cut negative. It is a two-stage process. First, a master positive (or interpositive) is made, and this is then copied again to produce a duplicate negative (or "dupe neg"), which is used for producing the release prints. In some archives, there may be material referred to as "CRI" (or colour reversal intermediate). This is a film stock that formerly was used to produce a dupe neg in one step and is no longer used.

Inter-negatives are made using a special colour negative stock, intended to produce a negative from reversal originals or print material. Unfortunately, the term inter-negative is also used for an intermediate negative produced from an intermediate positive. Broadly speaking, inter-negatives have a contrast similar to camera negatives so they should present no problems due to contrast range when transferred on a telecine. However, the colour reproduction may be difficult to handle as this depends heavily on the quality and type of original material.

11.5.3. Camera original stocks

11.5.3.1. Camera negative film

Negative film stocks have wide exposure latitude with tonal reproduction at a low-density range. Past and present stocks have a similar low-contrast reproduction. Most camera negative stocks have been made for film presentation. However, Kodak Primetime Film (5600 and 5620) were camera negative stocks specially designed with different contrast for the three colour layers, to match the spectral response of a typical telecine. Consequently, this film stock could not be used for making high-quality film prints. Negatives can have a higher contrast with non-standard processing. Extended development time – "forced processing" – can give a higher contrast but with poorer colour reproduction and increased grain. This technique was often used to try to overcome the effects of underexposure of the negative. Generally, negatives will only lose image information if they are seriously underexposed. Moderate overexposure does not normally lead to loss of image quality. Heavy overexposure leads to burned-out highlights.

11.5.3.2. Camera reversal film

Camera reversal stocks were originally made for direct projection. Black & white (e.g. Plus-x and Tri-x) and colour (Ektachrome and Gevachrome) reversal stocks were widely used for television news applications. The Kodak Ektachrome Commercial Films (7250 and 7252) were low-contrast reversal stocks (contrast = 1) from which an inter-negative was made for printing. Current reversal films designed for television have suitable densities to give good results on telecines if they are correctly exposed. Compared to camera negative, the reversal film does not have the same exposure latitude and is therefore more dependent on correct exposure and the choice of scene contrast. The processing of reversal stocks can be adjusted to reduce the maximum density and the contrast. However, the biggest variable is likely to have been the original exposure of the reversal film, which can lead to loss of image details in the highlights or shadows.

11.5.4. Film recordings (telerecordings)

The use of film recording (or telerecording as it is also known) was widespread in the television industry in the 1950s and 60s. At this time, videotape stock was expensive and thought of as a re-useable product, and not generally considered to be an archive medium. Film recording was a substitute way of preserving a videotaped or studio production on film. This was done, crudely speaking, by pointing a film camera at an electronic vision monitor.

Film recordings on negative stock are difficult to grade whereas film recordings on positive stock are more manageable. Other difficulties, when transferring film recordings using telecine, are the correction of artefacts caused by sync problems between the film camera shutter and the television monitor's field scanning process, as well as film grain, variations in picture levels, inherent television camera faults, mixer flashes, etc. There may be special problems from the interlaced structure of the photographed images – especially, for example, when transferring a 405-line recording to 625-lines. This is not to forget any problems with the associated sound. All this means that film recordings can push the telecine operation to extremes in order to produce acceptable results for archiving.

11.6. Choice of material to transfer

The inventory of existing material should be checked to identify the most suitable source of film material to be transferred.

The criteria for suitability should include the following:

- the film material closest to the original;
- material that poses the least technical problems during the transfer;
- the artistic intentions of the production staff.

For programme material shot on reversal film stocks, the original camera film will give the best image quality, provided that the material is in good condition and the splices will cause no problem for the telecine transfer.

For a programme shot on negative film, and where a print is available, two points should be considered:

- Is the print in good condition?
- Was the print specially prepared for telecine transfer or for optical projection?

Intermediate materials from traditional film productions, such as master positives and duplicate negatives, can be the alternative material for transfer. If none of these materials can be used and there are difficulties in producing a new print, there is the option of scanning the original negative. However, it should be borne in mind that the use of original camera negative material, intended for film printing, might pose major technical problems and the pictures might not match those on the original print.

11.7. Specific problems of transferring archival film

11.7.1. Image degradation

Differential dye fading is the most common image degradation phenomenon in archived colour films. This causes different colour, hue and saturation effects at different light levels of the image. These problems are difficult to deal with in traditional film grading and printing methods, if the fading in any one colour has exceeded

30% from the original light values used for grading. Electronic correction, however, can offer more sophisticated image-correction methods. The fading of individual dyes causes colour mis-tracking throughout the luminance scale, resulting in coloured neutral elements of the scene. To correct for this is a major challenge, even for "high-end" colour correctors. The ideal corrector will correctly reproduce neutral areas at all density levels and thereby also remove unwanted colour casts in parts of the picture.

11.7.2. The amount of image correction to apply to archival film

In the process of transferring archival film material, it is important to take into account the purpose of transferring the film material. The transfer might be for a short-term video usage of a film in good condition, or it may be to preserve a programme on an endangered film material.

When transferring archival film to video, it is therefore important to decide on a strategy for what shall be done in the transfer process, as there is an extensive range of corrections that can be applied (e.g. contour corrections, noise reduction, scratch and stripe suppression and image stability). It should always be taken into account that equipment performance is being improved all the time.

There are two strategic questions to be asked:

- Should images be corrected in the best possible way with all available equipment?
- Should the corrections be limited to the classical basic corrections (i.e. black, gamma, gain, and primary colour balance)?

The answers to these questions will depend on the strategy for reuse and the decision of the producer. The archivist might prefer a basic transfer, with corrections added later if necessary. The user of the archival material might like to access the material immediately, without having to wait and pay for further processing. In any case, after transfer, the film should be stored under good conditions for possible later transfer with improved quality, or for an alternative use.

11.7.3. Scanned area dimensions

The mechanical scanning aperture of any telecine equipment used to transfer archival material should be sufficient to capture all archival formats and image areas on 16mm, Super 16mm, 35mm and Super 35mm film. Ideally, the equipment should be able to memorise the most commonly-used scanned image area dimensions. Recently, harmonized standards have been agreed internationally for the dimensions of the maximum area to capture from 16mm and 35mm film gauges from different aspect ratio apertures. These dimensions can be found in EBU Recommendation R86 [22]. A further EBU Recommendation, R93 [23], gives a number of compromise scanning areas, which may be chosen for specific films. An alignment test film should be used to secure the correct scanned area and to ensure proper centring. Suitable films are available from BKSTS in London in Super-16mm, 35mm Academy aperture and Super-35mm formats *(see Figs. 11.1, 11.2 and 11.3)*.

11.7.4. Preparation of film for telecine transfer

Archival material should be checked to make sure that is in a proper condition before transfer. A specialist should carry out the operations discussed in *Section 9.2.*

11.7.5. Cleaning of archival film during transfer

After inspection and preparation for telecine transfer, the film should be correctly cleaned. To maintain cleanliness through the telecine transfer, the use of a dust remover is recommended, preferably using PTR rollers. It is important to avoid solvent cleaning for dust removal on film with tape splices, because the liquid will cause the tape adhesive to swell and lead to sticky splices, adhesive on adjacent film turns (film layers) and problems on a

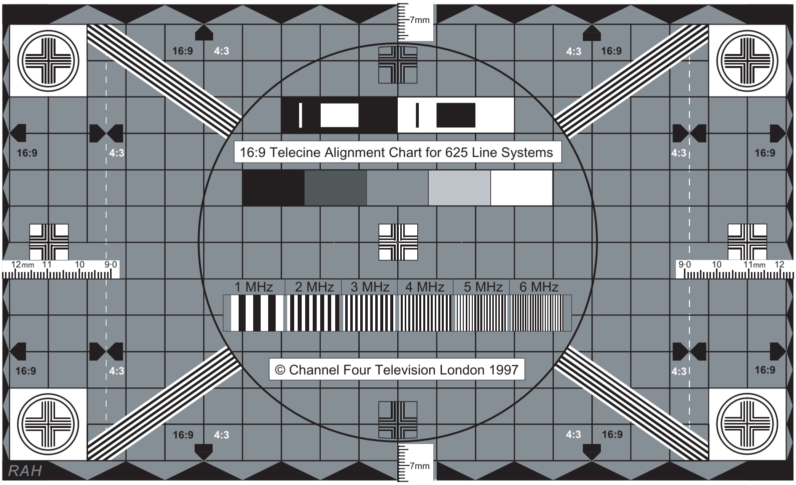

Figure 11.1
BKSTS super 16mm test film for the alignment of telecines.

capstan film transport. Wet-gate telecines will suppress scratches on the film support, but tape splices will suffer from the same problems as with solvent cleaning *(see Section 7.7.)*.

11.7.6. Film and SEPMAG shrinkage

A particular telecine will have a specified capacity to handle shrunken films, typical up to 2% shrinkage on a modern capstan-based transport whilst, for a sprocket-based transport, it is expected to be less. As with other transport mechanisms using sprocketed rollers, a ticking sound will warn that the film perforations are about to be damaged. A check of the shrinkage should be made in the process of preparing the material for telecine transfer *(see Section 8.11.)*.

SEPMAG sound followers can have a sprocket or capstan transport. The capacity of the follower to handle shrunken SEPMAG must be known when handling archive material.

11.7.7. Wet-gate systems

Most wet-gate systems use Perchlorethylene, a solvent that is highly toxic but with the essential property of a refractive index equal to that of the film base. A wet-gate system will conceal base-side scratches and shallow scratches in the clear supercoat on the emulsion side, and will minimize the visibility of dirt on the film. Wet-gate printing or telecine transfer will increase the contrast of the images.

A side effect of wet-gate operation, that should not be overlooked, is that the solvent will soften and swell the adhesive in any tape-splices. The adhesive is liable to cause problems by sticking to the capstan, any PTR cleaning rollers and the adjacent layers of film.

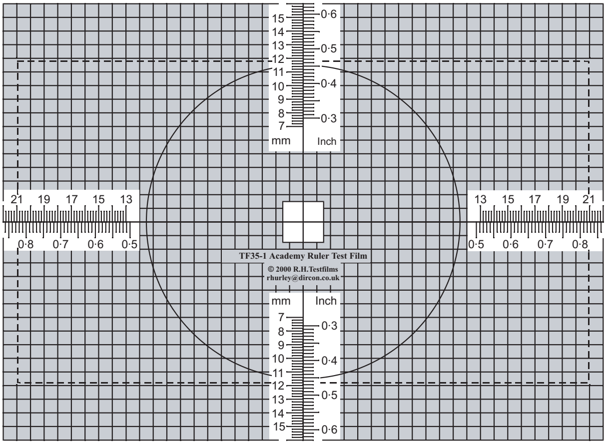

Figure 11.2
BKSTS 35mm (Academy) test film for the alignment of telecines.

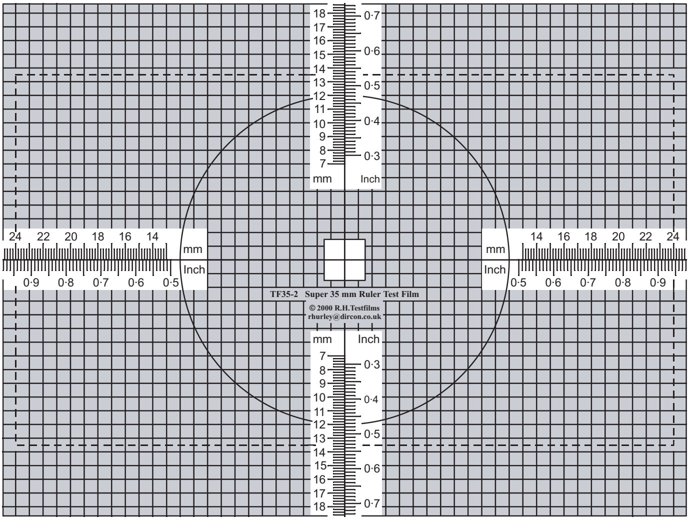

Figure 11.3
BKSTS Super-35mm test film for the alignment of telecines.

11.7.8. Separate magnetic sound (SEPMAG)

Depending upon the date of recording, the pre-emphasis used for 16mm SEPMAG recordings might have been 120µs, 100µs or, most recently, 70µs. The pre-emphasis should be correctly compensated for during replay to ensure that the frequency response is correct.

11.8. Telecine performance

Telecine performance has been improved along with other technologies over the last 40 years. Image artefacts from past scanning principles are no longer present. The capability to reproduce faithfully the inherent quality and resolution of film images has reached a point where significant further improvements in system performance are not expected.

Broadcasters should be aware that film programmes transferred to videotape in the past would benefit from a retransfer, using a modern telecine.

Chapter 12
Migrating from film for future television production

12.1. The valued properties of motion picture film

Motion picture film is rather different from videotape recordings. The exposed images are available for visual inspection or projection, and there is the unique property for television of being able to reuse any old film material for whatever future television system. The film information density is dependent on the film gauge, format, film speed, lenses and the post-production processes used. In the case of 35mm film, it is expected that the information density is beyond that of any HDTV television system, whilst 16mm film might normally be faithfully reproduced in standard-resolution television systems.

12.2. Options for a digital future

Several broadcasting organizations have already implemented integrated production systems based on servers. In future, television archive technology is expected to be largely based on servers. Broadcasters' film archives will have to adapt to these new concepts to provide services to internal production users and to external clients. Content management systems will be established to provide access to content based on metadata and browsing-quality images for previewing. This process may take some time to become common and will depend on the resources of individual broadcaster but it seems to be inevitable in the long run. The ease of gaining fast access to browsing and master signals will create demand for similar access to legacy programme material, including film. Server-based systems will offer new business opportunities to expose and exploit legacy material. All this will demand the digitization of film material.

12.3. The conversion process

Among the reasons to convert film to electronic media are:

- to enable fast access for future production and new archival concepts;
- to preserve endangered programme material.

Converting a large film collection will be an expensive time-consuming process. A migration strategy is needed. Beside the decisions to be taken on the value of the content, there are technical conditions and options that need to be taken into account in the strategy, such as:

- the inherent information density on the film *(see Section 12.3.1.)*;
- the image aspect ratio on the film *(see Section 12.3.1.)*;
- the production format(s) for future television production *(see Section 12.4.)*;
- the recording medium *(see Section 12.5.)*;
- the expected usable lifetime of the material in digital form.

Since the transfer of images from film is no longer to be configured for a known television production format, there is the need to take into account possible future configurations as well. This complicates the transfer and makes it necessary to discuss the details of properties and options before deciding on a transfer strategy and a migration route *(see Section 12.8.1.)*.

12.3.1. Information content of film images

The information content of some film images is much higher than that of conventional television. In the early 1990s, measurements were made of the typical resolution of film images, obtained under operational shooting conditions for TV programme production, using different gauges and stocks. *Tables 12.1* and *12.2* show the resulting spatial information density of the film pictures and the corresponding data-rates per film frame. These figures were derived from the actual pixel resolution per mm, by exploiting the MTF measurements (determined at 90% fall-off of the MTF function) of low-sensitivity film material. A colour depth of 10 bits for prints and 14 bits for OCN (Original Colour Negative) was assumed for the digitization. The effects of different generations of film processing were taken into account as well. The film stocks used were Kodak ECN 5245/7245 and 5248/7248 camera stocks and 5384/7386 print stocks. Ordinary cameras were used with fixed prime lenses (for 35mm) and zoom lenses (for 16mm).

Table 12.1
Typical information density of film pictures, in pixels per frame
(values reflecting the situation around 1990).

Film format	Image area e= exposed p= projectable		Aspect ratio 1:	See note no.	Pixels per frame (N)		Pixels per frame (N/Pr or N/IP/IN/Pr)	
		(mm x mm)			(k x k pixels)	(Mpxl)	(k x k pixels)	(Mpxl)
16mm formats								
Std. 16mm	e:	10.05x7.42	1.35	1	1.31k x 0.96k	1.26		
	p:	9.65x7.26	1.33	2			1.06k x 0.8k	0.85
Super-16mm	e:	12.35x7.42	1.66	1	1.6k x 0.97k	1.55		
	p:	12.20x7.35	1.66	2			1.34k x 0.8k	1.09
35mm formats								
Academy	e:	22.00x16.00	1.37	1	2.86k x 2.08k	5.95		
	p:	20.95x15.29	1.37	2			2.3k x 1.68k	3.87
	p:	20.95x12.62	1.66	3			2.1k x 1.26k	2.64
	p:	20.95x11.78	1.78	2			2.3k x 1.3k	2.99
	p:	20.95x11.33	1.85	3			2.1k x 1.13k	2.37
Cinemascope	p:	20.95x17.53	2.39	3			2.1k x 1.75k	3.67
Super-35mm (Full aperture)	e:	24.92x18.67	1.33	1	3.24k x 2.43k	7.86		
	p:	24.00x18.00	1.33	2			2.64kx1.98k	5.23

Notes: The above figures were calculated from the following numbers of pixels per mm on the film:

1) OCN. + Lens = 130 pixels/mm;
2) OCN. + Lens + Print = 110 pixels/mm;
3) OCN. + Lens + IN + IP + Print = 100 pixels/mm.

Terms:

OCN = Original Colour Negative; IN = Intermediate Neg (Dupe Neg); IP = Intermediate Positive

These information densities reflect the optimum condition of film in the early 90s. They may not apply in the case of older or newer film stocks.

Table 12.2
Typical data rate in MB per film frame or in GB per film duration
(Colour depth per channel: 14 bits for negative and 10 bits for print)

Film Format	Film type/s	Mbytes/frame	Gbytes/min.	Gbytes/90 min
16mm formats				
Std. 16mm				
1:1.33	N	6.6	9.9	892
1:1.33	N/Pr	3.2	4.8	428
Super-16				
1:1.66	N	8.1	12.2	1097
1:1.66	N/Pr	4.1	6.1	549
35mm formats				
Academy aperture				
1:1.33	N	31.2	46.7	4205
1:1.33	N/Pr	14.5	21.8	1960
1:1.66	N/IP/IN/Pr	9.9	14.3	1284
1:1.78	N/Pr	11.2	16.8	1512
1:1.85	N/IP/IN/Pr	8.9	12.8	1153
1:2.39 (Cinemascope)	N/IP/IN/Pr	13.8	19.8	1784
Super-35mm aperture				
1:1.33	N	41.3	61.9	5573
1:1.33	N/Pr	19.6	29.4	2646

Terms:

N = Negative; IP = Intermediate Positive; IN = Intermediate Negative; Pr = Print

The figures given in *Tables 12.1* and *12.2* represent a useful rule of thumb of the typical information content and data rates of images stored on film using technology in the early 1990s. They are not intended to be used to specify pixel resolution for film scanning, when digitizing film images *(see Section 12.3.2.)*.

12.3.2. Scanning resolution required for lossless digitization

For broadcast applications, it is difficult to decide whether to digitize high-quality film for current or for future television delivery systems, or to preserve the maximum information that is on the film.

Technology is now available to scan and digitize the full information available in film images. Experience with such equipment shows that a pixel pitch of 6µm (about 160 pixels per mm) is considered sufficient to reproduce current film stocks. This corresponds to a scan of 4k x 3k (actually 4096 x 3112) over the full aperture on 35mm film. If film is scanned at lower resolution (corresponding to a larger pixel spacing), less information is captured and more aliasing artefacts are introduced.

12.4. Digital video production formats

In the short and near term, it may be more time- and cost-effective to digitize archival material in a format that is simply related to a format used for digital production. This format will define the scanning raster, dynamic range, colour gamut and aspect ratio used in the archive.

Currently, the following options are available, in order of increasing quality.

12.4.1. Compression at 50 Mbit/s, DV-based or MPEG-2 4:2:2P@ML

Both DV-based [24] and MPEG 4.4.2P@ML [25] compression formats are based on ITU-R BT.601 video signals (see below). The resultant quality, although accepted for mainstream television production, may be lower than the inherent quality of the film. However, this approach will allow the immediate integration of archived content into the respective compressed production platform, and exploitation of additional functionalities such as faster-than-real-time transfer.

12.4.2. Uncompressed standard definition, ITU-R Rec. BT.601

ITU-R Recommendation BT.601 [4] is the basic standard for digital television coding in use now and for the foreseeable future. It could serve also as a useful archive platform should both of the compression systems listed above need to be supported.

12.4.3. HDTV formats

A range of high definition standards has been proposed, such as: 1920x1080@24 progressive, 1920x1080@50 interlaced, and 720@50 progressive. Digitizing to one of these formats will make it easier to exploit more of the potential of film material in the future. However, no clear choice has yet been made on which, if any, HDTV format should be used, particularly in Europe.

In spite of this, programmes might be exported to countries that are using HDTV, so this option needs to be considered – even if it cannot be justified for internal use.

12.4.4. Resolution higher than HDTV

The film industry uses film-to-video and video-back-to-film (“Digital Intermediate”) processes where the video stages use resolutions higher than HDTV. These have a typical horizontal resolution of 2k or 4k pixels *(see Section 12.6.4.)*. In theory, this higher resolution could match the resolution and image aspect ratio of any film. This would preserve the full quality potential of the original film and became an electronic clone of the original film material. The digital material could be converted electronically to any future production format.

For very valuable material on film – with considerable long term potential for use in TV production – such a transfer may be worth considering. However it seems unlikely that broadcasters will use such a system for general television production.

12.5. Video recorders

A factor in the decision process on any of the above production formats is the availability, or not, of digital video recorders. The current options (early 2001) are given below.

12.5.1. Compression systems at 50 Mbits, DV and MPEG-based

Video recorders are available for both DV and MPEG (IMX) based compression systems. These can be used straight away to record signals digitized to these systems.

12.5.2. Uncompressed standard definition

"Rec. 601" signals can be recorded on D5 format recorders [26] and the older D1 format. In addition, recorders using compression can be used in an uncompressed environment, if the loss of quality can be accepted. Both of the 50 Mbit compression systems above, as well as the Digital Betacam format, are generally considered virtually transparent for "601" signals and suitable for use in general television production.

12.5.3. HDTV

There are a number of VTR formats, some using compression, available for HDTV signals. The rapidly changing situation on the wide variety of HDTV options in use makes it difficult to state whether a particular HDTV option is supported or will be supported in the future.

12.5.4. Resolution higher than HDTV

To date (early 2001), no VTR is available to record 2K/4K component signals. In the "Digital Intermediate" film process, the signals are stored as data signals *(see Section 12.6.)*.

12.6. Data files

New television production methods, based on servers, will store and transfer video signals as files. This technology is not yet completely developed and standardized. The current (early 2001) options are given below.

12.6.1. Compression at 50 Mbits, DV and MPEG-based.

In both DV and MPEG systems, compressed video data files can be transferred between some equipment, (servers, workstations, VTRs). However, at the moment, these use proprietary systems. Work is currently under way to specify a standardized file format, MXF, which will be used for either compression system.

12.6.2. Uncompressed standard definition

Uncompressed "Rec. 601" video data can be transferred between equipment but, at the moment, only using proprietary standards. It is planned to develop the MXF file format above to contain uncompressed video data.

12.6.3. HDTV

Work is also under way to define a file format for HDTV signals.

12.6.4. Resolution higher than HDTV

Currently, the DPX file format [27] has become an industry standard for film production and electronic cinema presentation. These data files are more flexible than a television format. They can be scaled by near-lossless processing for different resolutions and image aspect ratios that might be used in future production and presentation systems.

At the moment, the DPX format does not meet the requirements of broadcasters because, for instance, it does not contain sound data or metadata. In addition, the files are very large and cannot be transferred in real time. Both are serious handicaps to use in television production.

12.7. Metadata

Metadata will be essential to find, retrieve and exploit programme material in the future server-based, carrier-less, storage environments. In the process of transferring archive film for server-based production or electronic archiving, it is essential to preserve existing metadata, such as production information, image content, textual descriptions, etc. This information should be gathered from existing sources such as paper reports, existing databases or even from the film itself, to form a minimum set of metadata for future use. The transfer process will also be a good opportunity to check and enhance the data.

12.8. Migration scenario

Most broadcasters have been transferring archive film for reuse in production for some time, but now there is an increasing need for rapid access to film material to exploit future production systems and new archival concepts *(see section 12.2.)*.

When film is transferred and recorded on a video production format, more or less severe constraints are imposed. The telecine will be configured to the desired resolution and image aspect ratio, and the signal for recording will be conformed to the defined recording format. The programme material is thereby locked into a certain configuration that is less flexible for future reuse than the film itself. Therefore, film in any condition should be properly stored for a possible later transfer.

The information above *(see Sections 12.3. to 12.7.)* leads to the following conclusions. It is important to choose a recording medium that will not create image artefacts due to encoding or compression – in order to preserve as much of the film quality as possible.

Current requirements for reuse could be met by transferring film as "Rec. 601" digital component signals. The preferred recording formats would be D5, which is fully compliant with ITU-R BR.601, 10 bits. Alternatively, Digital Betacam (compressed) could be used. The compressed platforms at 50 Mbit/s, DV-based and MPEG-2 422P@ML might reduce the inherent quality of film but these are frequently used for general broadcast production.

High-definition television systems are visible on the horizon but there are uncertainties about when these will become production standards for broadcasting. There are also several proposals for different delivery and production formats. Although the potential reuse for future HDTV should be considered before the transfer for server-based production, archiving and browsing ... at this point in time, unless there is a business plan for HDTV exploitation, it cannot be advised due to the high cost of the investments and the changes of production practice. Film can be transferred later when HDTV production formats and broadcast production environments are established. Equipment and services are available for those who need to meet specific requirements for HDTV production, exchange or preservation.

Transferring at even higher than HDTV resolution is possible, but none of the options to transfer at even higher definitions, such as 2K or 4K, are yet readily available for use in broadcast production. At the moment, the high cost and uncertainty over standards makes it difficult to consider preserving film material as these high-resolution digital signals.

12.8.1. Migration routes

Once a migration strategy has been decided, the migration routes can be planned. A migration route from film material is very different to that for from one video format to another. Film has inherent flexibility and can be exploited for a number of future needs. It is, however, necessary to take into account the slow access to film material in migration routes. This means the electronic versions created for long-term or permanent replacement, have to take account of future needs as well as the requirements of current production formats.

A migration route could be as follows:

- Check the film material for fading, active degradation, physical defects and damage.
- Decide which image quality the film represents, and what quality needs to be preserved. Film can then be divided into categories from the 16mm standard aperture and up to Super-35mm aperture with a resolution 4 - 5 times greater.
- Decide the capability of the telecine used for transfer. Is the transfer to become a fully graded version with correction of image imperfections and artefacts, or is the transfer intended for a “one light” transfer to be further graded and corrected later? What is the image aspect ratio to be transferred?
- Decide on the production format and signal configuration to be recorded. There is a range of telecines available, capable of scanning to current SDTV, future HDTV and even higher resolution standards.

See *Fig. 12.1* for possible migration routes.

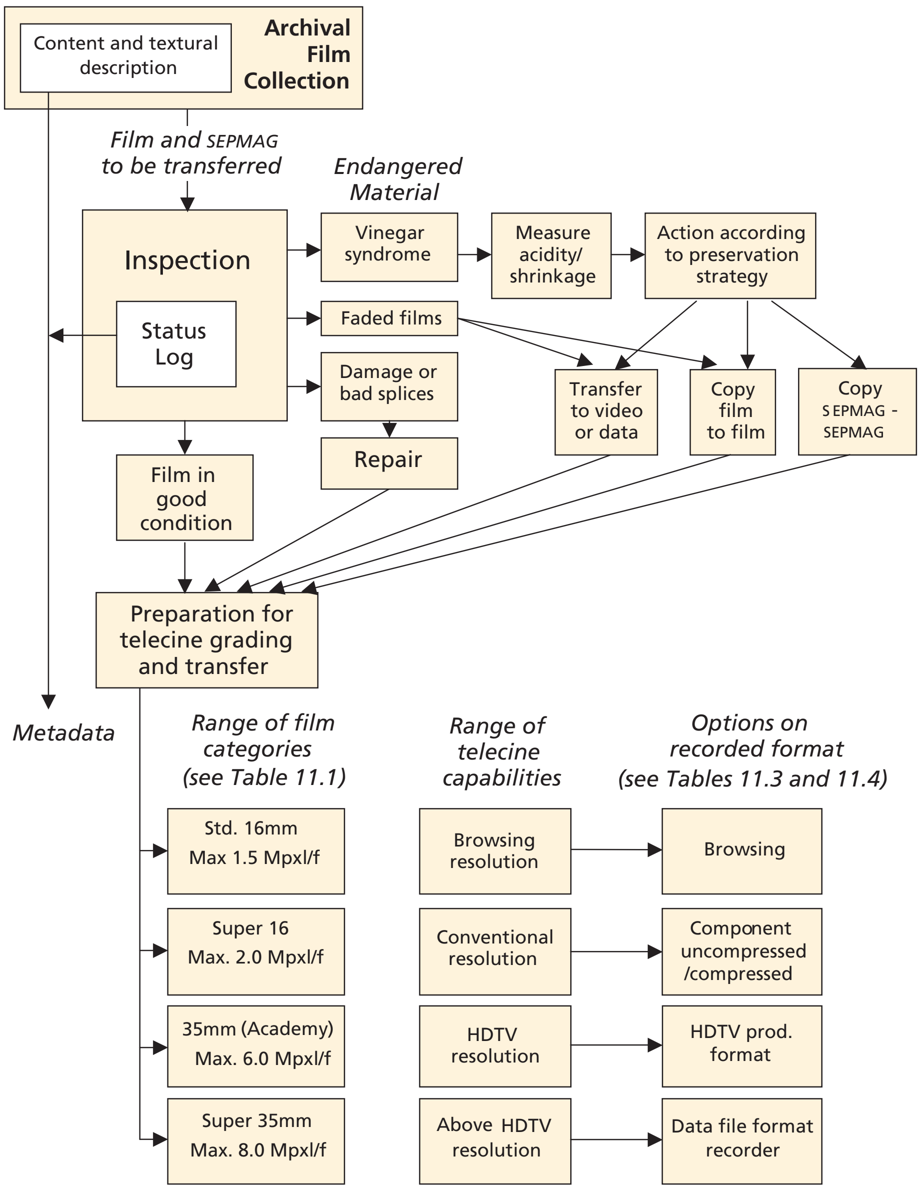

Figure 12.1
Process routes for the migration of film material to electronic media.

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