became its worst enemy, as the illegal exploitation of 'official' recordings and the unauthorised production of new ones suddenly became very quick and easy.

We have seen in this chapter how the political and economic factors influencing technical standardisation shaped the emergence of the related technologies of television and video recording. The next chapter examines the issues these and other factors raise in an activity which no one who designed the mass-produced moving image technologies ever really considered.

chapter seven | archival preservation and restoration

> The paradox of Theseus's ship, which poses the problem of conservation and restoration, has always fascinated me. The ship in which Theseus, slayer of the Minotaur, returned home from Crete, was kept like a sacred relic by the Athenians for centuries. Over the years the old pieces of wood had to be changed to save the vessel from the ravages of time, to such an extent that after so many replacements and substitutions, it could quite legitimately be claimed that the original ship no longer existed.[1]

> Surely it is the images that are the important thing, not the base that they are on ... Give me acetate or polyester any day: I'll take my chances with vinegar syndrome – at least it is easy to identify – and I'll sleep easy knowing that my vault is not going to go 'wallop' in the middle of the night![2]

Throughout this book so far I have used the adjective 'permanent' in relation to a number of recording media. All these uses make the implicit assumption that as soon as a reel of film emerges from the fixing bath, or a Vitaphone master was removed from the electroplating machine, or a videotape is wound onto its take-up spool, a moving image or sound recording has been created which is indelible and will last forever, unless someone makes the conscious decision to dispose of it or (in the case of magnetic tape) overwrite the media with a new recording. It has not and it will not. Although political and regulatory influences have played a part (e.g. in determining technical standards), the invention and development of all the technologies used to record moving images have been commercial ventures. The investors behind them believed – correctly, in the short term – that the money which was to be made out of the media content recorded using these technologies would be generated in a relatively short time following production. So by 'permanent', the individuals and organisations which used film and videotape usually thought in terms of weeks; months at most. Simply put, they neither knew nor cared what would happen to those media after that time.

The idea of systematically preserving moving image content as a public record did not come from within the media industries, but instead from museum curators, librarians and academics who believed that its cultural value was significant, even if its long-term commercial value was negligible. The first and longest established moving image archives, therefore, were and are public sector organisations. The idea of film preservation goes back almost as far as film itself; specifically to a pamphlet published in 1898 in which a Polish photographer described film as an 'honest and infallible eye-witness' of historically important events, and worth preserving on those grounds.[3] The first film archives (in any meaningful sense of the word) were established in Europe and the United States during the 1930s, under the umbrella of organisations such as the Museum of Modern Art (USA), the British Film Institute (BFI) (a government agency established in 1933 to promote educational uses of the moving image) and the Nazi propaganda ministry. Commercial film production interests (e.g. Hollywood studios) in most cases did not attempt to preserve their output beyond the point of initial distribution, and in some cases did not start routinely doing so until well into the 1950s. There were a number of reasons for this: vaults and storage facilities were expensive to build and maintain; even more so, given the health and safety precautions necessary when storing significant quantities of nitrate in one location. Furthermore, the principal commercial markets for archive footage – television and videotape sales – did not exist until the 1950s and 1980s respectively. Before that point, many studios actually destroyed prints (the silver in black-and-white film emulsion is recyclable and has a cash value) after distribution as a safeguard against piracy (see chapter six). It has been said that between 20 and 50 per cent of all commercially produced films and television output made in the developed world have survived, depending on whose figures you believe. Whatever the actual figure is, it is indisputable that a significant proportion has been lost.[4] This is not just because producers chose not to keep it.

Chemical decomposition of film

We recall from chapter one that all pre-polyester film bases are manufactured, essentially, by dissolving cellulose (a derivative of wood pulp and/or cotton fibre) in an acid of some description and then processing the resulting brew into a flexible, transparent solid. For the first half of the twentieth century the most common method was to use nitric acid, thereby producing cellulose nitrate film. During the period 1948–92 approximately,[5] this was substituted with acetic acid, the resulting compound being cellulose triacetate. While these organic materials (i.e. ones which are produced by mixing and processing naturally occurring substances) will keep their flexible and transparent properties for as long as is needed in the immediate production, distribution and exhibition process, it has been found that in the long term, they will decompose. Eventually, both nitrate and acetate film will decompose to the point at which the images and sounds on them can no longer be recovered.

The basic chemical process which causes this decomposition is common to both nitrate and acetate, a group of compounds known as cellulose esters. These chemical combinations are extremely susceptible to hydrolysis, a process in which exposure to moisture in the atmosphere can cause the acidic content to leach out of the film base, thus releasing nitric or acetic fumes into the atmosphere. Within

a sealed environment such as a film can, these acidic vapours attack what remains of the base, thereby sustaining the process. Nitrate decomposition is probably the most widely acknowledged, understood and addressed problem among the archive community. Archivists tend to prioritise preservation work on nitrate: possibly because, to borrow the words of a former curator of the UK's National Film and Television Archive, 'there is an end point ... the stuff just goes'.[6] The fact that some sort of chemical change takes place in the nitrate film base almost from the moment of manufacture predated the formal practice of film archiving by two to three decades. One industry commentator writing in 1910 described this change as 'a ripening, or seasoning process'[7] and various descriptions of the phenomenon can be found in other written sources from the early twentieth century. Very few, however, seemed concerned with ensuring the long-term preservation of moving image content: the vast majority of technicians and scientists who investigated the process of chemical change in nitrate film were mainly concerned with understanding and minimising the fire risk. Because nitrate was only manufactured on an industrial scale from the 1890s onwards, it is likely that hardly any of the film base in circulation would have started to decompose to the point of visibility for several decades afterwards. It was not until 1941, when the British archivist Harold Brown discovered a reel of nitrate which, in the space of six months, had started to 'go sticky', that a process of research began which eventually uncovered the full extent of the problem; i.e. that without preventative measures, the content of nitrate film would eventually be lost.[8]

By 1965, the decomposition process in nitrate was more or less fully understood. A report published by the International Federation of Film Archives (known by the initials of its French name, FIAF) in that year described it as 'the following sequence of physical changes: (i) the silver image undergoes a brownish discolouration and fading; (ii) the emulsion becomes sticky; (iii) there is a partial softening of the reel of film (formation of "honey"), the appearance of blisters and a pungent smell; (iv) the entire film congeals into one solid mass; (v) the film base disintegrates into a brownish powder, giving off an acrid odour. In this last stage the film has a very low ignition temperature and is highly explosive.'[9]

Tragically, the existence of the fifth stage had encouraged the destruction of nitrate both before and after systematic film archiving had come into existence. The early generation of technicians who had sought to understand the decomposition process quickly discovered that as nitrate film ages, it becomes more volatile, and that warm storage conditions can exacerbate the risk. In the unusually hot summer of 1949, for example, an abnormally high number of nitrate fires were reported to have taken place, in response to which a series of experiments was carried out to try and establish if nitrate was capable of spontaneous ignition. The abstract of the paper which reported the results makes a brutally stark recommendation:

> Cellulose nitrate film in the advanced stages of decomposition is liable to ignite spontaneously. The danger of such ignition is reduced by inspecting stored film stocks and removing and destroying all decomposing film.[10]

Of course it was not just decomposing film that was destroyed: throughout its existence as the principal film base in widespread use, destruction was the safety measure of choice for most stock which had become surplus to requirement.

When acetate superseded nitrate in the 1948–50 conversion, archivists thought they had the perfect solution to the decomposition problem. This took the form of a method which is known by archivists now as 'copy to preserve', i.e. photographically duplicating nitrate originals onto acetate stock for what they thought would be permanent preservation. To make things even worse, destruction of the nitrate originals after duplication was a routine practice, even among the more enlightened archives, for all the reasons given above (i.e. not wanting their vaults to go 'wallop' in the middle of the night). Indeed, there have been several instances of archive vaults literally going wallop: possibly the two best-known were at the Cinémathèque Française on 10 July 1959, when (again, on an abnormally hot day) it is believed that hundreds of feature films were irrevocably lost in a fire; and on 4 July 1993, when the Hendersons laboratory in South London, which specialised in archival duplication work, sufferd a similar fire which practically destroyed the building along with many irreplaceable elements. Both fires are believed to have been caused by the spontaneous ignition of nitrate.

When it was initially developed, it is not difficult to understand why archivists thought that cellulose triacetate was the answer to their prayers. At the time, nitric acid was thought to be the culprit where decomposition was concerned: so much so that the 1965 FIAF report stated emphatically that triacetate 'does not generate injurious gases and does not produce any symptoms of disintegration'.[11] Archives quickly adopted a strategy summed up by the slogan 'nitrate won't wait', of duplicating as much footage as possible as quickly as possible. An article written to launch a project intended to 'dupe' the National Film and Television Archive's remaining stocks of nitrate as late as 1987 declared that 'all nitrate material in Britain, whether in public or private hands, and irrespective of who owns the copyright, or what its historical "value" is thought to be at the present time, should be transferred to acetate stock'.[12]

In fact, triacetate was susceptible to decomposition; and as with nitrate, the scale of the problem took decades to emerge. Although triacetate is a compound based on acetic rather than nitric acid, the underlying chemical processes which take place during its manufacture are very similar.[13] Both nitrate and acetate are 'pendant chain' cellulose ester polymers, and as such are acutely sensitive to hydrolysis (reaction to water). In nitrate the result of this reaction is the decomposition process described above; in acetate it is slightly different, but just as destructive in the long term. By 1989, an updated version of the FIAF preservation manual acknowledged the existence of preservation issues associated with triacetate, noting that 'film manufacturers and research institutions have published further information about this grave problem, which they are currently investigating in greater depth'.[14]

The formal term for acetate decomposition is 'deacetylation' (loss of acetic acid from the film base). Among archivists it is more often referred to as 'vinegar syndrome', named after the characteristic smell of a deacetylating element. The initial

symptom is usually shrinkage, which causes difficulties in running an affected element through any film transport mechanism (such as a printer, projector or telecine) because the perforations become smaller and the space between them is reduced. The film base will then become warped and distorted, making it difficult to produce an image with uniform focus. As the process continues the base will become brittle, and the extent of the physical deformity will eventually prevent access to the images and sounds recorded on it. In an enclosed container, such as a film can, the increasing accumulation of acidic fumes will cause the reaction to become 'autocatalytic', i.e. self-sustaining to the point at which the rate of decomposition accelerates.

It has been understood for decades that as a rough rule of thumb, storage in cool and dry conditions can inhibit the decomposition process of both nitrate and acetate. Until the early 1990s, however, it was not believed that atmospherically controlled storage could extend the service life of nitrate or acetate to the point at which this was a viable preservation technique to replace copying it as soon as possible. One significant milestone came in 1985, when the Image Permanence Institute (IPI) was established in New York. This was a research organisation, bankrolled by film and equipment manufacturers, set up in order to identify solutions to a number of problems related to the long-term preservation of film, photographic paper and electronic images. Within a decade, their scientists had established that the 'nitrate won't wait' approach of prioritising copy to preserve above all other methods might not be the most effective solution.

Preservation methods: 'copy to preserve'

Copying to preserve film is essentially the same thing as duplicating it during the production process, as described in chapter one. Ideally this will be done using a continuous contact printer, because placing the source and destination stocks in direct physical contact with each other minimises generational fading, while the full width aperture in a continuous printer will also duplicate information outside the photographic frame itself (such as camera apertures and markings which archivists can use to identify the date and location that the original stock was manufactured) which can be useful to preserve. But this method is not always possible if the original element has suffered decomposition or other physical damage, and for this reason a range of archival printing techniques have been developed for obtaining the best duplicate material possible from poor quality elements. The problems which may need to be addressed as part of the duplication process are physical defects affecting image quality (such as scratches or mould growth on the base or emulsion surface) and physical defects affecting film transport (shrinkage, brittleness or perforation damage).

A number of techniques have been evolved in order to address these problems during the duplication process. Step contact printers have proven effective in dealing with shrunk or deformed base, though sometimes at the expense of picture stability in the duplicate, because of the fractional difference in the size and position of each frame relative to each other. This in turn can be corrected to a certain extent using a step optical printer, but at the expense of contrast and definition loss introduced by the lens. 'Wet gate' printing can reduce the visibility of scratches on the original. In this method the original element is immersed in a liquid with a similar refractive index to the film base itself. This liquid has the effect of 'filling in' the indentations in the film which are visible on the screen as scratches, because as light passes through it onto the destination stock, the liquid refracts it to an almost identical extent as the film base itself.

It is now understood that destruction of original elements after duplication is potentially a very bad idea. There are two key reasons for this. Firstly, we now know that close control of environmental storage conditions can extend the service life of a nitrate or acetate element for much longer than had originally been thought (of which more below); and secondly, the duplication technology at archivists' disposal is evolving and improving all the time. For example, in 1989 FIAF advised that 'serious problems' would be encountered if any attempt were made to duplicate significantly shrunken stock using the continuous contact method.[15] In 2004, however, a continuous contact printer designed specifically for archival duplication went on the market, which is claimed by its manufacturer to be able to handle elements with up to 2 per cent shrinkage, without any visible effect on picture stability in the duplicate.[16] So, for example, a nitrate element with slight shrinkage that had been duplicated in the 1970s could now (assuming that it had not suffered any further decomposition in the meantime) be copied again, only to a much higher image quality. Furthermore, the widespread availability of polyester film base from the early 1990s onwards provides what is almost certainly a much less problematic alternative to triacetate for use in copying nitrate originals. While some doubts have been expressed about the long-term stability of the method used to bind the emulsion layer to the base, it is generally believed that, being an inorganic substance, polyester will prove to be a far more resilient medium on which to create archival preservation masters. This would, of course, be impossible if an original element had been destroyed after the initial duplication in the 1970s. But, nevertheless, destruction following duplication remained standard practice for many commercial footage libraries (who did not want the risk and expense of maintaining large quantities of volatile material) and public sector archives (which could not justify the cost both of preservation copying and storing the originals). Even the advice leaflet on nitrate handling and storage issued by Eastman Kodak advised destruction until it was revised in 2002 to suggest that only elements 'which have reached the third stage of decomposition or have no historical value' should be disposed of.[17]

Preservation methods: passive conservation

The growth of passive conservation as an archival preservation strategy is not so much a case of new technology appearing as the greater understanding of the effectiveness of an existing one. Coupled with a growing realisation that copying methods were improving over time, research carried out by the IPI and a group of scientists at Manchester Metropolitan University in Britain had, by the mid-1990s, established

that temperature- and humidity-controlled storage could extend the life of both nitrate and acetate elements for a lot longer than was previously thought possible.[18] Among the key findings of these research programmes was that reducing humidity had a bigger impact than temperature in inhibiting the decomposition process, that nitrate did not necessarily decompose more quickly than acetate, and that by maintaining optimum conditions, the service life of an original element (assuming that it had not previously been stored in inappropriate conditions for any significant length of time, which of course most have) could be extended for hundreds of years rather than tens, as was previously believed.[19] In the light of this work many archives have began to move the emphasis of their preservation work away from 'copy to preserve' to a 'passive conservation' model. In 1994 an IPI scientist argued that 'it is time to broaden the scope of film preservation activities and abandon a narrow focus where copying in anticipation of future decay claims such a large share of funding and staff resources'.[20]

For most archives these resources are finite, hence the use of environmentally-controlled storage of the original to buy time for preservation copying. Unlike with videotape preservation, in which the problem of format obsolescence prevents such an approach, a combination of storage and monitoring can be used to delay, often for centuries, the moment at which an archival master element has to be duplicated in order to prevent loss of content through decomposition. To this end a number of collection management tools have been developed. For detecting deacetylation in triacetate elements the IPI supplies a testing device which is supplied either as a paper strip similar to Litmus paper (the 'acid detection strip' or 'a/d strip') or a semi-transparent plastic stud which is mounted in a hole punched in the side a film can. This will change colour according to the concentration of acetic acid vapour inside the can, thereby indicating the extent of decomposition.

The most reliable test for nitrate decomposition is slightly more complicated, as it involves using the 'accelerated aging' process. This is a technique developed by the Swedish chemist Svandte Arrhenius in 1887. It is based on the principle that if the speed of chemical change is induced primarily by heat, then by artificially increasing the level of heat exposure it is possible to simulate the effect of lower heat levels over a greater time period on a given substance. In the case of nitrate film, this is done by taking a small sample of the element being tested and placing it in a test tube containing an indicator dye which is formulated to change colour in response to nitrogen dioxide released from the film. The time this takes is

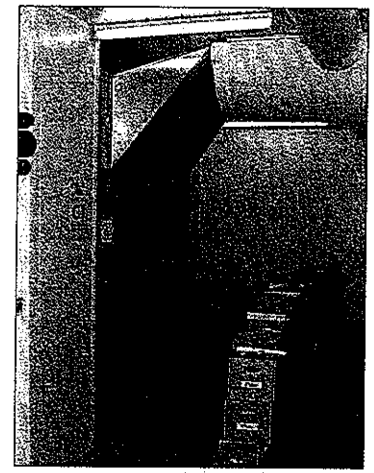

Fig. 7.1 Passive conservation – temperature and humidity control in an archival film store. Air from the vault passes through the filter at the bottom of the air handling unit. Inside the unit it is cleaned of acidic vapours and then cooled and dried before being recirculated through the manifold at the top. The fabric channels mounted on the ceiling will allow air to pass out, but not in.

proportional to the remaining useful life of the element when stored in appropriate conditions.

Through a combination of atmospheric control in storage areas and tests which can identify and predict the rate of decomposition, it is possible to inhibit and manage the process of film-base deterioration to the point at which most elements can be stored for centuries. This ensures that the only copies which need to be produced are for access purposes and removes the need to proactively make copies which may well be of lower quality than ones made closer to the moment at which they are actually needed for viewing.

Colour dye fading

This is yet another example of a decomposition problem which was only discovered thirty years or so after the affected technologies entered mainstream use. The emergence of dye-coupler colour emulsions in the 1950s (see chapter three) proved to be the catalyst which marked the beginning of the end for black-and-white as a mainstream production medium for feature films, as it was significantly cheaper and more versatile than any of the alternatives which had previously been available. The fact that all three subtractive colour dyes were combined onto a single strip of film made colour cinematography possible using normal, unmodified cameras and without the extra camera rental, film stock, lighting and laboratory costs incurred by the three-strip Technicolor process. Unlike the single-strip reversal stocks which had been used on a limited scale by amateur filmmakers in the 1930s and 1940s, it could be mass-duplicated using the negative/positive system with no more generational loss than was caused by any other form of analogue duplication. But this was only achieved by the use of some fearsomely complicated chemistry, and therein lay the problem.

These stocks contain three chemical layers which are photosensitive to each of the primary colours. The developing process activates the chemical coupler, which converts the substance from a photosensitive emulsion into a visible dye of its corresponding coupler. In the late 1960s it was established that these chemical reactions did not cease altogether after the film was processed. In fact, the dyes which form the green and blue layers on a positive element (cyan and magenta on a negative) fade gradually over an extended period of time, with the result that the overall colour balance is disrupted and the image takes on a pink hue. This phenomenon only affected Eastmancolor negatives and reversal materials derived from this technology (colour reversal intermediates were found to fade especially quickly); Technicolor dye-transfer prints were immune, because no chemical changes were induced in the substances which formed the dyes after application on the gelatine-coated film base, thereby making these elements very stable as far as colour was concerned. However, most dye transfer elements were nitrate, as were the vast majority of camera negatives (in a sad turn of fate, the film industry abandoned the three-strip camera in favour of Eastmancolor just as acetate superseded nitrate). Technicolor separation elements therefore suffer their own colour preservation issues, largely arising from the three strips shrinking at slightly different rates, thereby making it very difficult

to combine them accurately. Kodachrome (apart from the first generation of stocks sold between 1935 and 1938) was also found to be extremely stable, though as a relatively high contrast reversal stock it was difficult to copy and therefore never used on the same scale as Eastmancolor. The Eastmancolor fading process was described by one writer as follows:

> The first colour elements to fade are usually the yellows and the greens. Since these are frequently the softer, less intense colours, their absence is less obvious. A change in flesh tones occurs, and the outdoor scenes are less vital ... In the extreme stages of colour fading, the picture images are gradually reduced to ugly pinkish purple shadows of the original.[21]

Even after the problem was discovered, progress in researching possible solutions was complicated by a number of high-profile campaigns which, to all intents and purposes, accused the Eastman Kodak company of being negligent in marketing colour film which was prone to fading. Perhaps the most vocal was headed by the prominent film director Martin Scorsese, who repeatedly called for action on Kodak's part in formulating new stocks which were more resistant to long-term dye fading.[22] As part of his campaign he screened faded prints at the 1980 New York Film Festival and secured the support of prominent art-house directors, including Federico Fellini, Jean-Luc Godard and François Truffaut.[23] The end result was the introduction of so-called 'low fade' coupler stocks by Eastman Kodak, starting with type 5384 35mm print stock in 1981, and subsequently by its two principal rivals (Agfa-Geveart and Fuji). But by that point archivists had been given a legacy of thirty years' worth of colour film elements which had either gone pink or were at risk of doing so; and, due largely to the public criticism they had received, film manufacturers were reluctant to co-operate in researching the problem or releasing their own data.[24]

The research which Scorsese's campaign kick-started revealed that as with cellulose ester base decomposition, colour dye fading can also be inhibited by storing elements in atmospherically controlled conditions. Unlike with triacetate base (nitrate is not a significant issue here, because Eastmancolor was not introduced until just after the nitrate/safety conversion), coupler dyes are more sensitive to temperature than humidity, though vinegar syndrome in the base can catalyse and accelerate dye fading. As a general rule, the colder the vault, the slower the fading process. Colour film stores are therefore kept at far lower temperatures than their equivalents for black-and-white or magnetic media, and some archives even go as far as to freeze colour elements in hermetically-sealed plastic shrink wrap (at that temperature, the production of off-gases from deacetylation is not considered sufficient for sealing to increase the risk) to prevent contamination from the moisture produced by artificial refrigeration systems. However, the cost of maintaining freezers is considerable, and some archivists are reluctant to freeze films because they fear that damage may be caused during the freezing and thawing processes.

If it is too late for preventative passive conservation of coupler colour elements and significant fading has already taken place, a number of 'copy to preserve' methods, both analogue and digital, have been developed which attempt to restore the colour balance of the newly processed element. The digital approach is covered in the following chapter. Some of the analogue methods can be surprisingly effective, but none are cheap or straightforward. Probably the cheapest option is to make an 'as is' telecine transfer of the affected element and then manipulate the colour balance using video post-production technology. However, the corrected version will then only exist on video and will not be available for viewing with the higher tonal range and resolution of film. As an alternative, the colour temperature of the light used in a printer can be manipulated to compensate for the disproportionate density of the three dyes, thereby producing a better balanced duplicate (on coupler stock).

Until the emergence of digital methods, the 'gold standard' in colour restoration was an adaptation of the Technicolor method. The affected element would be printed three times, through red, green and blue (or yellow, cyan and magenta, depending if the source element was a positive or a negative) filters onto panchromatic black-and-white stock. This would produce three separation negatives, similar to those exposed in the three-strip Technicolor camera. When a new colour print or video master is needed for viewing, the three negatives are exposed consecutively onto new coupler colour stock, thereby reconstituting the three colour records. Since the master colour records themselves are black-and-white, the accurate long-term preservation of colour information is therefore guaranteed, as the silver which forms the monochrome emulsion is known to be extremely stable and not prone to fading or any significant chemical change. At the time of his campaign, Scorsese promoted this method of preservation heavily, demanding that studios create separation masters immediately after completion, before dye fading necessitated any attempt at restoration.

That having been said, none of these restoration methods are foolproof. When manipulating the colour balance during duplication of an element which is already faded, no objective means exists of determining the original colour balance of the source element in order to compare it with the copy. The restored colour record, therefore, is often based simply on what 'looks right' to the laboratory technician doing the grading, or sometimes from evidence outside the film itself, such as the colour of reference landmarks photographed in the film.[25] When printing separations as preservation masters at the point of production, extreme care needs to be taken in order to ensure that accurate registration can be obtained when recombining them into a new negative. To be absolutely certain that an accurate colour record for preservation has actually been obtained, it is necessary to print a new coupler internegative from the separation masters, even though one may not be needed to produce viewing materials for many years into the future. But doing so adds even more to the already high cost of this preservation route, with the result that many studios simply have not bothered.

Preservation and restoration

From this discussion of the way archivists have addressed the colour dye fading issue, it will have become apparent that we are really talking about two separate

activities. Firstly, we have *preservation*, which, broadly speaking, can be defined as the technologies and methods used to prevent damage or decomposition to audio-visual recordings from happening in the first place. Examples of preservation activity include the use of temperature- and humidity-controlled storage conditions, restricting the use of preservation elements in a way which risks scratching and pre-emptive copying to preserve (i.e. printing separation masters as soon as the production of a film is complete). *Restoration* is what archivists are forced into doing if effective preservation has not taken place, i.e. the only copies of a film which are known to survive are not believed to represent what a film would have looked and sounded like in its original state. Altering the colour temperature of the light source used in printing in order to correct dye fading in a duplicate element comes into this category, as would wet-gate printing to mask scratches. Film restoration involves doing either or both of two things:

> While 'restoration' refers to visual quality of the image, 'reconstruction' refers to a philological activity of putting the programme or narrative back to something like an 'original'.[26]

Given that the activity Paul Read and Mark-Paul Mayer term 'reconstruction' also involves making changes (as distinct from preservation, the object of which is to keep an element in the same technical condition as when an archive received it), this discussion will use the terms 'technical' and 'reconstructive' do distinguish between these two forms of restoration.

The object of technical restoration is usually to correct physical and/or visible defects in an original source element or to copy it in such a way that those defects are not reproduced. If an archive holds more than one copy of the same footage, the first stage will usually be what is termed 'technical selection'. This involves examining all the available elements and determining which one is in the best condition and should therefore be used to produce the restored version. All the relevant aspects of an element's condition will be examined and noted, including which generation it is, whether it is complete, the extent of any base decomposition, shrinkage, perforation damage, poor splices, scratching on the base or emulsion, colour dye fading and contamination by other substances (such as mould growth or projector oil). Where a large number of copies exist for a given title, the element used to make the restoration may be pieced together from sections taken from several of them, in order to form the best quality copy of the film as a whole.

A number of treatments and processes can be applied to the source element itself in order to minimise the effect of any defects when it is duplicated. Ultrasonic cleaning, in which the film is immersed in a liquid through which ultrasonic energy is conducted, can be used to remove dirt. Adhesive tape can be used to replace or reinforce damaged perforations. Dried up cement splices can be remade after scraping away the residue. The underlying rule of thumb which any responsible archivist seeks to follow when making changes to original elements directly is not to apply any treatment which is irreversible unless there is absolutely no alternative.

For example, chemical treatments which are routinely used in cinema projection boxes for cleaning release prints (e.g. Filmguard, Renovex, Ecco) would not be considered acceptable for archival restoration, as the long-effects of those chemicals are not fully understood and may be impossible to undo. The chemicals used in ultrasonic cleaning, on the other hand, have been thoroughly tested and are known to evaporate without leaving any residue. The adhesive tape used to repair perforation damage can, if necessary, be removed without trace. If the restoration process does involve assembling a master element from a number of different sources, meticulous record-keeping as to what was taken from where will enable each source to be returned to its original state if required. And if a soundtrack is rerecorded (for example, for purposes of noise reduction), the original (or a 'straight' duplicate, if the original is at risk of decomposition) will be kept for reference.

The object of reconstructive restoration is not necessarily to correct technical defects. This is carried out when the *content* of a film is not known to survive in the way that it would have been shown on its initial release or distribution, and a number of different sources are used to reassemble it. While this is a similar process to using different sources to produce a 'best' master element in the sense of image and sound quality, it is being done with a different aim in mind. Let us take one hypothetical example. Two copies of a Hollywood 'B' feature from the 1930s are known to survive. One is the edited camera negative, held by the studio's own archive. However, three scenes are missing from it because the film was re-released a few years after production. For the second release the censors demanded cuts, which were effected by simply removing footage from the original picture and track negatives before the new prints were struck directly from them. The missing sections have since been lost. The library of a major television broadcaster holds a release print of the same film, which dates from the original release and therefore includes the censored scenes. But other footage was removed, as this 78-minute film was arbitrarily cut to fit a 70-minute broadcast slot, and the deleted sections were simply thrown in the bin. In this scenario, a dupe negative of the censored scenes could be struck from the television print and the footage cut back into the camera negative, thereby enabling the complete film in its original state to be duplicated for preservation. As the censored material would be at least three generations removed from the camera negative there would be a noticeable drop in image quality as it appeared in the new version, but at least we would be able to see the film as it was originally shown.

This is a very simplistic example, but it does illustrate the principles used in reconstructing films which, for a variety of reasons, may not have survived in their original state. Perhaps the most celebrated film reconstruction ever undertaken was Kevin Brownlow's work on the five-hour epic *Napoléon* (1927, dir. Abel Gance) in the 1970s. This used literally hundreds of source elements, consisting of everything from sections of camera negative to 9.5mm prints. The end game in any restoration which involves direct technical intervention on original elements is duplication – there is no point in only passively conserving an asembled element which has undergone restoration work, as it will almost certainly not be viewable in this state.

As has been illustrated above in relation to colour dye fading, this stage can also introduce technical changes in order to correct physical defects in the original (such as optical and/or wet-gate printing).

There is an ethical dimension to restoration work which is not as big an issue when simple preservation is the object of the exercise. This relates to the question of what, exactly, constitutes 'original', and whether that is what you're aiming to restore. For example, Jacques Tati's debut feature, *Jour de fête* (1947) was filmed simultaneously using two cameras, one of which used an experimental colour process known as Thomsoncolor (a dry-screen system not dissimilar to Dufaycolor), and the other of which exposed conventional, panchromatic black-and-white stock. It proved impossible to produce any colour release prints, and therefore the film was released in black-and-white only. But the Thomsoncolor negatives survived, and in the mid-1990s a restoration project was undertaken in which they were copied onto coupler stock and the film was re-released in colour.[27] Could the restoration legitimately be described as recreating the original film, given that the colour version had never been seen when the film was initially released?

There have also been occasions when a simple lack of communication has resulted in some very contentious 'restoration'. The British director Bill Douglas's autobiographical feature *My Childhood* (1972) was shot on 16mm Eastmancolor stock, but the release prints were struck on black-and-white deliberately, in order to give the image a low-contrast feel which Douglas hoped would evoke the look of Edinburgh in the 1950s. When a new print was made for screening at a festival shortly after the filmmaker's death in 1991, no one thought to tell the lab about this, with the result that the film was screened in colour for the first time.

Even more ethically contentious are those 'restorations' which quite deliberately seek to re-release a film in a different form to that which was seen upon initial release. At least the colour negatives of *Jour de fête* were artefacts from the original production, even if it proved impossible to screen their content at the time. As an example of contentious technical restoration, *Vertigo* was never released nor intended to be released with six-channel stereo sound, but that is exactly the form in which it was 'restored' for redistribution in 1997. And how do we define 'original' where reconstruction is concerned? If a celebrated director is overruled by studio bosses, who cut or reedit his film, which is 'original' – the version approved by the director or the version that was initially seen by the public? The number of 'director's cut' videos on sale from the mid-1990s onwards would suggest to the cynically minded that, despite the potential complexity of the question, its existence is being commercially exploited with impunity. Sometimes a director himself will make changes to a film after release, as was the case with *Lawrence of Arabia* (1962, dir. David Lean), when approximately 20 minutes of footage were trimmed in the months following the initial screenings. Most of it was recovered and reinstated when the film was restored in 1989. One review questioned the decision to do this:

> When a film is cut on grounds other than censorship, there is generally good reason for it results in a tighter, faster, more compelling picture ... We are talking here of making films

as good again as they were when new. Too many other restorers are making them worse and more tedious than they have seemed for years.[28]

While to a certain extent this journalist is missing the object of the exercise (whatever you would call re-editing a film to enhance its attractiveness to a mainstream audience, it is not restoration), the definition of 'original' which an archivist uses to underpin the nature and extent of any reconstruction or technical intervention highlights the importance of what Paolo Cherchi Usai called 'the old debate on what curatorial expertise should render unto Caesar and what to God'.[29]

Preservation and restoration of videotape

In maintaining moving image content originated on (or, at any rate, which exists on) film, it will have become apparent that archivists have been given a mountain to climb, thanks mainly to the medium simply not having been designed with longevity in mind. The videotape mountain is even higher. Being an analogue medium which is delivered through the technologies of chemistry, optics, simple electronics and mechanical engineering, the images and sounds on film are relatively straightforward to recover. The intermittent mechanism and other key components of a printer can be modified to cope with shrunken or brittle stock, faded dyes can be reprinted by using prisms and filters to control the colour temperature of the light source used to print it, dirt can be removed simply by cleaning the film itself, and so on. Furthermore, the effectiveness of international standardisation has kept the number of gauges and formats in circulation comparatively low, thereby minimising the equipment and expertise needed to maintain archival film collections.

In terms of the preservation challenge it poses, videotape differs from film in two crucial respects. Firstly, the hardware needed to record and play back the images and sounds is far more complex. Secondly – and as we have seen in chapter six – the role of standardisation was never as effective in television and video technologies as it was with film. From an archivist's standpoint, the wrong precedent had been set as early as 1941, when the adoption of the NTSC broadcast standard made US broadcasting fundamentally incompatible with the British 405-line system. When Ampex introduced the first 2-inch studio VTRs in the late 1950s, separate versions had to be made for NTSC, 405-line and subsequently PAL, each of which was completely incompatible with the others. Every subsequent generation of broadcast standard videotape technology has entailed a fundamental redesign of the way in which signals are encoded on the tape, the design of the spool or cassette and the design of the VTRs. As a general rule of thumb, the standard videotape format used by broadcasters and producers changes every decade or so. When this happens, the superseded tapes become what is known as a 'legacy format', meaning that manufacturers no longer provide equipment, blank media or spare parts.

This creates real problems for archivists charged with maintaining collections of legacy format tapes. The are basically two ways they can proceed: one is to maintain legacy format VTRs as well as an inventory of spares and the expertise needed to operate and maintain them, while the other is to undertake the video equivalent of 'copy to preserve' in film, a process known as 'continuous format migration'. This is exactly as it sounds – undertaking to copy all media to a new format before or as an old one goes from current to legacy. The cost of this is significant, and as with the archives which until recently destroyed nitrate originals after duping them, a decision has to be made as to whether to keep the original after duplication. If so, this has storage space (and therefore more cost) implications. Furthermore, and again, as with film, the copying process introduces generational loss. Ultimately, some sort of format migration will be unavoidable if the content of legacy videotapes is to be preserved; and unlike nitrate film, there is no known way of putting off that day for centuries – and only just for decades. This is because of the sheer complexity of the mechanical and electronic systems inside a VTR, e.g. the helical scan head system, the tape transport mechanism and the integrated circuits needed to process the video and audio signals coming in and out of the machine. It simply would not be possible to build a 2-inch VTR with which to copy a collection of 1950s tapes from scratch in the same way that it would be possible to build a printer for copying shrunken 35mm nitrate.

Conclusion

During the second half of the twentieth century the technical processes of archival preservation and restoration of moving image content originated on film and videotape have become a key part of the way our access to moving image heritage is technologically mediated. With both film and video, these processes fall into one of two categories: *preservation*, which attempts to safeguard the technical integrity of content as it is received by the archivist, and *restoration*, which affects technical changes to it in order to recreate the look and sound of content which is believed to have existed once, but no longer does in that state.

Almost all the techniques used to do this have been evolved in arrears, so to speak. Indeed, the need for any 'techniques' at all (other than simply putting films on a shelf and forgetting about them) did not become apparent until over three decades after film had become big business and a mainstay of cultural activity, when the process and implications of nitrate decomposition started to be understood. History repeated itself when it came to developing the techniques and technologies for enabling preservation and restoration in other areas, notably in dealing with vinegar syndrome and dye fading. Perhaps the key reason for this is that, unlike the evolution of technologies for originating and financially exploiting moving images, the technologies needed to preserve them did not originate in the commercial sector. Indeed, the majority of moving image content was not deemed to have any significant monetary value after its initial release, a situation which persisted until the 1950s when the growth of television created a new market for archive film. In the public sector archives of most developed countries, moving image preservation has tended to come some way down the pecking order in allocating money and other resources, even though moving images are probably the most difficult and expensive form of archival document to preserve.