ELSEVIER

RESTORATION OF MOTION PICTURE FILM

Paul Read &
Mark-Paul Meyer

Restoration of Motion Picture Film

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Restoration of Motion Picture Film

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for the Gamma Group

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Contents

Editor's preface

This book has been written from material supplied by members of the Gamma Group. This committee of individuals represent their organizations on the Group with the common purpose of researching, sharing and promoting the technology of preservation and restoration of archive film. The group came together as partners in the European Union FORCE Film programme in 1990 in order to create a training programme for young technicians in film archives and specialist film laboratories, and then stayed together in order to carry out several research and evaluation programmes, some with similar funding.

In an unusual relationship, the member organizations comprise film archives, and commercial laboratories and specialists that have traditionally provided archives with preservation and restoration services. The group is essentially a group of individuals, whose speciality is archive film technology, rather than just the cultural issues surrounding film.

Although the membership is restricted, due to the limitations on funding both meetings and projects, and because the group was established with a European membership, in recent years a number of "corresponding members" have been drawn into the group to complete programmes and to provide more world wide coverage.

Although in origin some of the content was part of training programmes, and some has already been presented as technical papers at conferences and film festivals, more than half was written for this book.

Our intended readership is archivists and technologists, and so we not seek to explain photographic or motion picture technology, except where it is considered necessary to explain a technique, or where the historical technology is not widely known or understood. The first part provides a quick overview of film technology from the standpoint of a film restorer and conserver, and is therefore highly focused. However, the bibliography lists a number of basic texts.

The coverage will never be complete, or perfect, we know. As an example, some 150 different colour systems have existed as finished films, and we certainly have not been able to give more than a handful a specific reference. Sound restoration is another area that certainly warrants its own publication, and the sound content of this book is not intended to be definitive.

Finally there is the issue of digital restoration and digital access, which is given some space here but will clearly become the major medium for access, will be used for restoration, and could become important for preservation as well. This technology is changing and developing so quickly that this should really be the content of the next edition!

Two of the original members retired since the manuscript was begun, some new members joined as the Gamma Group members increased in number, and two of our corresponding members have contributed to this text. Some of the following list contributed a great deal to this book, but all of them played at least some part in its content.

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Paul Read
February 2000

1

Introduction to the restoration of motion picture film

The twentieth century is the century of the moving image. Since cinema was invented in the last years of the nineteenth century, it has developed as one of the most important manifestations of popular culture and mass media. An incredible quantity of moving images have been produced, many of them of historic or artistic value. They are the visual memory of over a century and many of these films are worth preserving for the audiences of today and of the future. This book is not about the cultural or historical value of films, nor about economic values or copyright issues. This book is about the technical, theoretical and practical aspects of film restoration.

Film restoration is essentially duplication. Motion picture film is an artefact that consists of a transparant plastic base on which a photographic emulsion has been coated. Both plastic base and emulsion are subject to degradation and it is impossible to separate them from one another. Duplication is therefore the only way to safeguard the moving image, but photochemical duplication techniques have their intrinsic limitations and therefore every duplication is a alteration by comparison with the source materials. Unlike in fine arts, in film restoration the original artefact is the source for a restoration. The original artefact can be repaired and cleaned, but the process of self-destruction cannot be stopped. The only way to preserve these films for later generations is to duplicate them onto modern film stock.

1.1 TERMINOLOGY

This book is not about passive conservation of film material. It is a fact that storage conditions are essential to stretch the lifetime of a film as much as possible, but most films will, some day, become subject of degradation and can only be saved through restoration.

The terms **conservation** and **preservation** are used in either an active way or a passive way and can therefore mean storage or even duplication without particular interventions and in principle without any loss of photographic information. The terms **restoration** and **reconstruction** are usually used when differences are created between the materials you start with and the materials you end with, through manipulating the process of duplication (restoration) or through editing sequences in a different order (reconstruction). However, from the text in this book it will become evident that a standardized duplication (preservation) without manipulating the photographic duplication process is almost impossible without loss of photographic quality. The quality of a duplicate is not guaranteed by standard procedures. It is one of the goals of this book to establish standards for film restoration, within the boundaries of today's technical possibilities.

When we speak in this book about restoration we mean the whole spectrum of film duplication, from the most simple duplication with a minimum of interventions up to the most complex ones with a maximum of manipulations. Since every duplication procedure has some decision moments which may influence the quality of the final product, it is important that certain principles are respected. For instance, restoration implies that it is not sufficient simply to transfer the information on a film to another carrier, which could involve video transfer as well, but to maintain as much as possible the original format of the film, in particular 35 mm and 16 mm cinematographic film.

It is important to be aware of the fact that many terms, names and indications for certain materials differ from country to country and almost from period to period. This is partly the fault of the industry, which introduced film stocks under certain names and then some years later introduced another film stock under the same name, or a name that was used previously by another manufacturer. But also those who use these terms often do not use them in a very considered way. If somebody speaks for instance about 'internegatives' or 'dupe negatives' it is not always certain that he or she means the same as you. To help with this possible confusion, the book has a glossary of terms, giving most cross-references.

1.2 WHY FILM RESTORATION?

Of all the films produced up to the early 1930s, when sound film was introduced, it is estimated that about 70–80 per cent have been lost. The losses of film from later periods are less dramatic, but still considerable. Even the original negatives of many films from only a few years ago have been lost, or are in a deplorable condition.

There are many reasons for this situation. Sometimes there were economic reasons – films were neglected or destroyed when no longer profitable. There were practical reasons – people wanted to get rid of that dusty heap of films and make use of the space! There were aesthetic reasons – old films were considered 'primitive' as the language of film became more 'sophisticated'. Silent films were destroyed when sound was introduced, the emulsion was washed from the base, silver was reclaimed from it, inflammable nitrate films were destroyed when nitrate film stock became prohibited ... etc.

Even without human interventions or negligence, films also destroy themselves. Films on a nitrate cellulose base, which were used until the early 1950s, are notoriously chemically unstable. For several decades duplication onto acetate cellulose or safety film stock was considered sufficient to preserve the films for the centuries to come. But today we know that safety film is almost as unstable as nitrate. The so-called 'vinegar syndrome', the name applied to acetate film decomposition because of the typical vinegar smell, is now threatening film collections all over the world. This decomposition process cannot be stopped and a film from 1990 may need a thorough restoration, just as much as a film from 1910.

Besides these physical reasons, it also important to recognize that 'old films' are appreciated now by a large group of people. More and more universities have departments specializing in cinema and its history, and even in film restoration. Today, there is also an important association for early cinema studies, Domitor, which has become an important and highly respected academic research group. There are festivals which present exclusively archive films in Pordenone, Bologna, Paris and Los Angeles. And film buffs become more and more aware of the fact that if you want to see a great film from the 1940s or 1950s, it is not necessarily the case that there will be a good print available. Contemporary film makers working as avant-garde artists discover that the cinema of the early days is in some ways as experimental as their own products, almost a century later. In general it is possible to say that in the past ten years there has been a growing interest in the aesthetic, narrative, cultural and documentary aspects of films from the past. In consequence, there is a growing awareness of the urgency to restore films before they are lost completely.

1.3 WHICH FILMS TO RESTORE?

Many decades ago people were aware of the fact that films were going to get lost and that something had to been done to save them for later generations. Although concepts and ideas for film archives already existed from the early days of cinema, the film archives as we known them today were created in the 1930s. Stockholm was the first in 1933, then Berlin, London, New York (Moma), Paris and Brussels followed in the years to follow. In 1938 the International Federation of Film Archives (FIAF) was founded and today more than 100 archives in over 60 countries collect, restore, provide access, exhibit films and document the entire history of film cinema, from the early days up to today.

But of course, the FIAF archives are not the only archives in the world. There are many local archives, company archives, private collections etc. where valuable materials are kept. All these archives and collections are the cinema treasure holders of our society. And these treasures will remain inaccessible and even disappear if we do not restore them.

Depending on the profile of the archive, different selections with different purposes are made for film restoration. National archives or archives with a regional status often have a role analogous to that of national libraries, archives or museums and therefore collect and restore films focused on a particular geographical area. Most of these archives will not be interested in film because of its aesthetical or cinematographic aspects, but will consider the moving images mostly as a document with historical information. Film museums or archives focused on the presentation of films will collect and restore artefacts and films from a film historical, film critical or film aesthetic point of view. Sometimes the institutionalized film history is the most important reference point for these archives; other archives may be more interested in unknown films, the small masterpieces that have not become part of film history. University and academic archives may have a mixture of different approaches or collect and restore films with certain research purposes. On the other hand, archives can be thematic and highly specialized, like the ethnographic collections, or collections dedicated to one format, or one person. Broadcasting archives and studio archives often preserve materials only for immediate access, but several broadcasting archives and some major production houses in the film industry have taken a conscious approach to the restoration of their own products. Finally, it is important to realize that there are still private collections, sometimes of outstanding quality and richness.

Although most archives have criteria related to the form or content of a film, some archives have a pragmatic approach in the sense that they restore all films which are requested for access, or which have a very limited life-expectancy.

1.4 HOW TO RESTORE?

Film restoration is not a new concept. But attitudes and techniques have changed over the years and therefore film restoration today is unlike film restoration 25 years ago. In very general terms, it is possible to say that film restoration was principally based on the idea of the reproducibility of photographic information. There was, for instance, little interest in the colours of tinted, toned, stencilled and handpainted films from the silent era, which were duplicated onto black and white safety stock. 35 mm films were often duplicated onto 16 mm, or a full frame silent frame was duplicated with an Academy frame to make the films accessible for theatres with standard projectors, even though considerable areas of image were lost, especially on the left hand side in the location of the sound track area. Or films were stretch printed (printing every other frame twice) to create a sensation of an 18 frames per second projection, when the projector was run at a standard 24 frames per second. It is significant to realize that original films and prints were often destroyed after duplication. This is no longer accepted, and it is sometimes painful to see that restoration could have been done much better today if the originals had not been destroyed.

Duplication materials have been improved considerably over the years. In the early days ordinary camera and print stock was used for duplication, which created severe contrast problems. The first duplication materials for black and white were introduced in the late 1920s and only then was it possible to make reasonable duplications. For colour films the same problems occurred for many years. In the beginning colour films were duplicated by using the colour films available at that time. They were neither very accurate nor were their dyes at all stable. When in the 1960s the colour internegative became available, the technique of copying colour and coloured films was not well advanced, nor were the techniques to simulate the tinting and toning of a print by exposing a colour print film by multiple passes of a black and white duplicate negative.

Thirty years ago commercial film laboratories used only standard techniques and were very inflexible in adapting their processes, and archives were not able to demand that their work be done to different standards or using different principles to that of the general run of laboratory work. In consequence, all archives and early film collections have examples of truly monumentally bad duplicating that dates from a time when archivists did not know that good quality could be achieved and when laboratory technicians were not trained, nor interested, in handling archival films. There was often very little control of contrast and most laboratories did not have the printing equipment to solve the problems that archival films raise. Good examples of these problems are the non-standard framelines which can be easily solved by racking the image in an optical printer, or the problem of shrinkage which causes unstable images in the duplicate, and which could be solved by specialized or replacement drive systems. Wet gate printing systems, used to reduce the effect of scratches on the film base, were not utilized for archive restoration until some ten years ago.

Today, most film archives and specialist film laboratories are aware of the fact that mere duplication of the photographic information of a film is not enough. Films are not interesting only for their information or narrative. The treasures in the archives are often not properly safeguarded when no justice has been done to the aesthetic quality of the films, either by an accurate duplication or in a conscious restoration. Early films are being rediscovered not only for scientific research or historic documentation but also for appreciation, for being able to create an aesthetic experience. In addition, the concept of quality has become far more important in the past 15 years and much more attention is now given to all those aspects that determine the aesthetic experience: the right frame ratio, the right projection speed, live music accompaniment and also the colours of early films.

1.5 STEPS OF FILM RESTORATION

This book gives in detail all the steps involved in the restoration process. For a good overview it is useful to keep the steps in mind for the duplication of a silent positive print. Let us say the film is already identified and research has pointed out that this a unique print. The following steps refer to the film laboratory restoration process:

Step 1 A film needs to be repaired and cleaned for printing. Repair is particularly necessary in order to avoid problems during the duplication procedure, to avoid the films being damaged in the printing machine, or to avoid unstable images in the restored print.

Step 2 Grading: The grader estimates the printer cues and printer lights needed for each scene. If all scenes of a print are duplicated with one and the same printer light the final result will be usually worse than the original.

Step 3 Printing: Duplication is done in a printing machine, from a negative a positive and from a positive a negative. In this case from the nitrate positive print a duplicate negative was made.

Step 4 Processing: The newly made duplicate negative needs to be processed. Processing is the term given to the chemical procedure of development of the latent image to produce a visible image and its subsequent stabilization.

Step 5 Grading: Grading of the duplicate negative from which a new positive print is to be made.

Step 6 Printing: The positive film stock will be exposed in the printing machine.

Step 7 Processing: The exposed positive print needs to be processed.

Step 8 Quality check of the final positive print.

1.6 DIGITAL TECHNOLOGIES

Finally, some words about the new digital technologies. Although technical and economic obstacles are still to be overcome, it is beyond any doubt that these difficulties will be reduced within a few decades, maybe even years. For film archives, there are two reasons for being enthusiastic about the new technologies. First, the limitations of traditional photographic techniques can now be overcome to some extent. Secondly, the concept of archive access will undergo a metamorphosis, changing completely film archive access policies and practices.

It is beyond any doubt that every film archive will, in the future, continue to have large collections of films on film stock. The simple reason for this is that every archive wants to be able to present a film in its original form. Film archives are, or will become, museums of the cinema, in the true sense of the word 'museum'. It is the responsibility of every film archive to keep the cinema 'alive' by enabling an audience to undergo a true 'cinematographic experience'. Sometimes this will be done by recreating as closely as possible an original presentation, in other cases it will be the creation of a new presentation geared to a contemporary public to enable them to appreciate the cinema in its full sense. To make this possible every film archive in the future will still have vaults containing 35 mm films, originals or restored duplicates. Most of these restored films will probably have been duplicated by traditional photographic means, but some of them will be partially or entirely restored by digital techniques.

If we look at the second principal purpose of film archives – conservation and restoration – we will see that certain aims of film restoration which are impossible to fulfil with traditional techniques may be realized in the future with digital techniques. For instance, very sophisticated but obsolete sound systems from the 1950s are probably better reproduced with digital techniques than with analogue re-recording.

In one aspect, digital technology will alter film archives considerably. Next to the collection of films, every archive will have an enormous collection of films in a digital format, most of them at television broadcast resolution. It is even probable that many films will survive only in a digital format. An access collection of this kind cannot be considered as a collection for museological preservation. Of great interest, however, is that it will make the archive's film collection accessible by computer, whether for research or education, for broadcast purposes or commercial distribution. Maybe parts of the collection will also be available on the market in a commercial format like CD-Rom, DVD and video-on-demand, or through the internet. Students, for instance, will have access to entire films as easily as they now have access to digitized newspaper reviews, stills or other documentation from the archive.

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Part 1

CINEMATOGRAPHIC TECHNOLOGY

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2

Light, sound and audiovisual perception

2.1 LIGHT

Prior to the nineteenth century, using the term 'visible light' would have been totally meaningless. However, in 1800–1801, William Herschel and Johann Wilhelm Ritter expanded both ends of the light spectrum as defined by Isaac Newton in 1666, on having shown that light contains invisible forms of energy which extend beyond the range of red and violet. Light is now defined as a minor part of a larger whole range of electromagnetic radiation from gamma-rays to radio waves. Light is distinguished solely by being visible to the human eye.

All forms of energy, which are grouped together as electromagnetic energy, can be defined as either waves or particles. Based on their total energy, they must be defined as being particles; and in the specific case of light, the term 'photons' or 'quanta' of light is used. When defined in terms of how their vibrations evolve, the term 'wavelengths' is used.

2.2 PROPERTIES OF VISIBLE LIGHT

Sources of light give off energy spanning the full breadth of the spectrum, but may do so to different degrees of intensity on the different wavelengths. Within this scope, sunlight includes a certain range of intensities among waves of different lengths, and it is this distribution which is referred to as white light. Other light sources give off radiation with distribution of intensities that give rise to what is known as colour dominance. The concept of light intensity denotes the total amount of radiation given off by a source per unit of surface area and is measured in lumens or in candles. Likewise, the luminosity which an object reflects (brightness) is measured in lumens or in candles per unit of surface area.

The concept of colour temperature, which is measured in Kelvin degrees (K°), is linked directly to the apparent combustion temperature of the light source in question. The higher this temperature, the higher its colour temperature, the greater the total amount energy of the radiation given off and the shorter the wavelength of the dominant radiation will be.

Materials that do not emit any visible radiation, reflect and/or absorb the light. The different amounts of each wavelength, combined with the distribution of intensities which characterizes each light source, results in the different colours in which matter is perceived.

2.3 SOUND

Just like light, sounds comprise part of a much broader family of waves ranging from the vibrations caused by earthquakes, frequencies even much lower than one cycle per hour, up to ultrasound. The longitudinal waves which are perceptible to human ear are defined as being sound waves.

Longitudinal waves are vibrations of matter (involving stages of compression and rarefaction) which indicate the absorption and transmission of the kinetic energy transferred by any type of impact. The total amount of energy in movement, the surface area covered, and the type of vibrating movement involved (depending upon the material and its shape) determine the properties of these waves. When the waves strike and penetrate different mediums, their properties vary and change through the processes of reflection, refraction or diffraction. These vibrations (the waves) vanish into empty space. The rate of speed at which they travel also depends upon the medium through which they are moving. For sound waves, the speed in dry air at sea level is of 331.4 metres/second; in the atmosphere with a 50% RH, it increases to 340 m/s and, in glass, about 5000 m/s.

A longitudinal wave of any type is characterized by its frequency or period, which measures the length of one cycle, by its amplitude or height of the wave front, and by its intensity. Waves of the same frequency or amplitude can be of different heights or periods. Sounds may be of several frequencies said to be in harmony (musical notes), or not in harmony (described as noise!) with one another. Their intensity depends upon the amount of energy transmitted per cm^2 per unit of time; and, as a result of their intensity being linked to their frequency and amplitude, determines their loudness.

2.4 THE SENSE OF HEARING

Sound waves, which are picked up by the external ear (a large aperture microphone!), are converted into vibrations and are amplified by the tympanic membrane (eardrum) and the incus, malleus and stapes all working together as one. When these vibrations reach the cochlea through the scala vestibuli and scala timpani, they arrive at the cochlear duct, which is located between these canals and contains some 5000 individual Corti bodies, each one of which vibrates under the effect of a specific range of frequencies.

All of these organs function as a whole like an analogue-to-digital converter which transmits a specific signal in response to each frequency detected. It has been shown that the human ear is capable of hearing frequencies from 20 to 20 000 cycles/second, at intensities of 0 decibels (dB) (hearing threshold) to 120 dB (pain threshold). The hearing sensation (loudness) is not the same throughout all of these ranges. A sound of 80 dB is audible throughout the entire range of frequencies, whilst a sound of 20 dB will be heard solely within the 200–15 000 cycle range.

Wavelengths vary depending upon the direction in which the source transmitting the waves is moving, becoming shorter in the direction of movement and lengthening in the opposite direction. On shortening, light waves move toward violet, and sound waves toward high frequencies; on lengthening, they move toward red and low-pitched tones. The speed at which sound travels makes it possible to immediately distinguish whether the source of the sound heard is still or is moving.

2.5 THE SENSE OF SIGHT

2.5.1 Parts of the eye

The human eye can be described as being a dark room equipped with lenses and devices for adjusting focus and brightness. In the eye, the dark room is the corpus vitreum or vitreous body. The lens assembly is comprised of the cornea and the crystalline lens. Focus is achieved by means of the combined effect of the optic nerve and the sclera. Brightness is adjusted by the contraction of the iris, which can expand or contract the diameter of the pupil within 1.8 mm–10 mm range. And the retina serves as the screen, equivalent to a film, on which a latent image is formed to be transmitted to the brain and processed in a region devoted especially to vision.

2.5.2 Light and colour perception

There are two types of light-sensitive organs making up the retina, that is, the cones, totalling some 7 000 000 in number and concentrated around the macula lutea; and the rods, totalling some 170 000 000 and scattered over the entire surface of the retina. When light strikes the surface layer of the retina, it triggers an initial response reaction by a pigment. The cones and rods, which are located in the next layer, react in turn (respectively to strong, coloured lights and to dim lights). These reactions (acid reaction to light/alkaline reaction to darkness) give rise to electrochemical impulses, which, via the optic nerve, transmit the visual sensations in each eye to the organ in the brain specially devoted to vision.

The human eye is capable of distinguishing among a wide range of differing degrees of brightness, being able to discern brightness values over a range of 1–10 000 000.

2.5.3 Field of vision, line of sight and peripheral vision

Although both eyes working together cover a 210° horizontal field and a 120° vertical field of vision, the ability to see is not the same over the whole area of the retina. Despite this wide-angle field of vision, the object being viewed must remain focused on the macula lutea (the area most sensitive to light and to colour) in each eye. Binocular vision, where both eyes are used and the images of the object viewed are focused on the macula luteas, achieves the maximum degree of visual acuity. This need for convergence sets a minimum limit on the distance at which it is possible to focus clearly on objects. In research experiments, it has been established the outer limit of the human focal range is located approximately 12 cm from the back of the retina. When focusing on objects located more than 6 m away, the human eye focuses in a long-range perspective.

2.6 AUDIOVISUAL PERCEPTION

2.6.1 Stereoscopic vision and persistence of vision

Seeing is not a continuous process. Each light-sensitive cell takes time to complete its electrochemical reaction, to discharge and to then ready itself once again. In research experiments, it has been proved that vision is discontinuous, and that the brain's vision centre recreates 10–12 images/second.

In some way which has not as yet been fully elucidated, the transmitting organs or the brain itself organizes the signals given out by the cones and rods into sequences of signals. These are routed from the retina to the vision centre in the brain and are stored in an orderly fashion until the time at which they are fully scanned and then interpreted in the proper order. The sight mechanisms do not allow a new image to be scanned until the scanning of the previous one is complete. This stop–start aspect of vision is provided for by means of a 'memory' mechanism which 'holds' each image in the brain's vision centre until it is replaced by the next one in line. This memory, formerly referred to as 'retina lag', is now known as persistence of vision. By combining (or making changes in) the information received from each eye (binocular vision), due to space apart between the pupils, the minor differences in alignment and positioning perceived by each eye make it possible to see objects in perspective (i.e. in three dimensions).

2.6.2 The binaural effect

Progressive learning is one aspect of vision. The eyes see solely what they look at, and, in this regard, are similar to a film camera. However, the sense of hearing always covers the same field to either side of the listener. It is therefore possible – in conjunction with the relatively slow rate of speed at which sound travels and with the reception of echoes caused by sound waves bouncing off the surroundings – to sense the presence of invisible, still objects and shapes and the movements of the sound-emitting sources.

2.6.3 Audiovisual perception

By means of the mechanisms of binocular vision and the persistence of vision, outdoor images are perceived in perspective, and each image received is superimposed on the following one for purposes of viewing continuity. The eyes (and the entire body) are in constant movement, and these consecutive images rarely fully coincide. The light coming from a point on an object strikes the retina at a different place each time. Under these conditions, the superimposing of different consecutive images will be perceived as blurred.

At the same time as the stop–start process of vision is taking place, the semicircular canals in each ear – organs, not apparently involved in the sense of hearing – provide constant, exact information regarding the position of the head in relationship to the Earth's gravity. This stereo information is picked up by the ears in the semicircular canals and processed by the hearing centre in the brain. The data together with the eye's stereo information processed by the vision centre in the brain plus an analytic integration element as yet to be definitely located, provides the information that we refer to in general as 'audiovisual perception'.

3

Before motion pictures

3.1 WRITING WITH LIGHT: THE FIRST PHOTOGRAPHY

Man's knowledge of the changes that light causes in some metal compounds dates back prior to the birth of photography. Research in this field led Ritter to the discovery of ultraviolet light, and records exist of experiments conducted at the beginning in the eighteenth century using light directly for reproducing images. The slowness of the reaction and, above all, the lack of a method of fixing the image thus obtained permanently by stopping the darkening of the metal solution, put an end to the research.

3.1.1 Black and white pictures

The research that led to the birth of photography was based on the blackening of metal compounds by light. The picture resulted from differences between the areas blackened. This was a black and white picture.

The blackening reaction is much faster when the higher-energy areas of the spectrum are used, and the first emulsions were sensitive solely to ultraviolet and blue light. Orthochromatic emulsions, which were sensitive to blue and green light, and panchromatic emulsions sensitive to the entire spectrum, required the addition of organic dyes. These emulsions were first developed toward the end of the nineteenth century, the first commercial panchromatic emulsions being marketed in 1906. Now, there are emulsions which are sensitive into the infrared portion of the spectrum.

3.1.2 Silver bromide

The initial attempts at taking photographs were made using silver nitrate solutions, but research soon focused on the use of other salts (iodides or bromides), in the mid-nineteenth century. Silver bromide combined with small amounts of silver iodide, forming crystals about one millimicron in diameter and containing hundreds of thousands of metal ions, is now the most basic ingredient in modern photographic emulsions.

3.1.3 Latent image

When light strikes a silver bromide crystal, some silver ions, depending upon the amount of light that strikes each crystal, are converted to metallic silver. If the exposure to light is sufficient, all of the silver ions will be converted to silver. At low exposures just a few ions are converted to metallic silver, forming a very faint image, virtually invisible, of the light received. This image is known as a latent image.

3.1.4 Photographic speed and developing

After exposure to light, films undergo a chemical process – development – which acts on those crystals that have been struck by the light and have latent images.

Developing employs an aqueous solution of reducing agents such as hydroquinone, Metol and Phenidone. The silver of the latent image acts as an inducer and a catalyst of a change in which all of the silver ions in the crystals containing latent image will be turned into black metallic silver. The extremely minute dimensions of the latent image will be multiplied thousands of times over, and by this magnification the metallic silver image will become visible.

Following development, the fixing process – using another aqueous solution – dissolves all the silver crystals that have not been developed to silver. This process stops the film from continuing to turn black on being exposed to further light, thus fixing the picture taken.

3.1.5 Film speed, definition and grain

The ability to reproduce the fine details of the objects photographed (the definition) of a film and how small the exposure need be made (speed) are linked quite closely to one another.

An emulsion's speed is a measure of the amount of light required to form a latent image sufficient to be developed. The definition in a photograph depends on the size of the silver bromide crystals and on how they are spread throughout the entire layer of the emulsion. The larger the bromide crystals are, the greater their probabilities of being struck by a quantum of light and the faster the emulsion will be. However, the larger they are, the larger the developed silver grains, and the larger the grains the lower the film's defining-power.

In the areas of the emulsion which were brightly illuminated, a latent image can form in all of the crystals, which will react during the developing process to turn into metallic silver grains and appear black. No exposure produces no development and no black silver. The intermediate tones will depend upon the number and the size of the crystals converted.

Early photographic plates had to be 'prepared' immediately prior to use and to be developed immediately thereafter. It was not until the mid-nineteenth century that stable emulsions were devised that would retain their light-sensitive properties for weeks, months and even years from the time of manufacture, before processing.

3.1.6 Photographic 'emulsions'

Many different approaches were used to solve the practical problems. In 1851, a nitrocellulose derivative, pyroxilin, was used to manufacture wet collodion emulsions, achieving a major improvement in speed. Ten years later, a dry form of this was used to make the first truly practical photographic plates, which did not have to be prepared immediately prior to use. In 1852, gelatines began to be used as emulgents for silver bromide and, from then on, silver bromide and gelatine would become the substance used worldwide in photographic emulsions.

3.1.7 Gelatine

Gelatines are natural organic proteins which are found in the skin and bones of many animals and which can be put to many different uses (in photography, they are also used for manufacturing filters). Solidified gelatines (as a gel) as support for photographic silver bromides provide consistency and flexibility and also contain certain active impurities which improve the light-sensitivity of the metallic salts.

Gelatines are used in biology as culture media for many different fungi and bacteria, which can also multiply in photographic emulsions under the right humidity conditions. Although they can be easily killed, permanent damage can be done to the transparency of the gelatines on which they feed. Thousands of films have been damaged or completely destroyed as a result of this property of gelatines.

3.2 POSITIVE – NEGATIVE – POSITIVE

3.2.1 Light to dark: negative–positive film systems

The brightness of objects is directly proportional to the amount of light they emit or reflect. Similarly, the resulting blackening of a photographic emulsion is also proportional to the amount of light absorbed. An image of light that forms in the emulsion will be developed in the form of increasing blackness, or

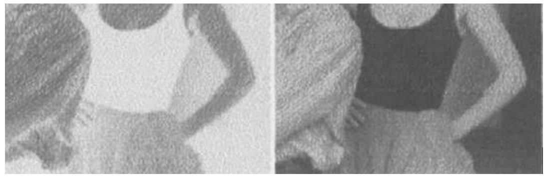


Figure 3.1 Monochrome negative and positive images of the same scene

density. An image that reverses white into black is known as a **negative,** an image that is not acceptable to the eye as being a facsimile of the original. By **printing** a second picture from the negative, the process of reversing the light values will be repeated, and a right reading image results. This second image is referred to as a **positive** or a **positive print**.

3.2.2 Colour reverse: colour negative–positive film systems

The colour emulsions have the same reversal of brightness as the black and white films. However, not only are the tones reversed but the colours as well. Red, green and blue reversed, are cyan, magenta and yellow, called complementary colours.

A black original will be white on a colour negative, just like on a black and white negative. A dark red image will be a light shade of cyan.

3.2.3 Negative and print on one same film

In 1814–37, Niepce and Daguerre invented the Daguerreotype, in which the negative and the print were made one after the other on the same plate. Other systems have continued using the same negative/print relationship. In these systems, the image is first developed as a negative to then be destroyed by means of a bleaching process, and those areas containing no image are exposed to light again or undergo a chemical blackening and are developed as prints.

3.2.4 Original negative and prints

Producing the final print on the same film as the negative yields high quality images but prevents several prints being made from each negative. This procedure is rarely used in the motion picture industry, although one film, called Direct film, does exist. The methods for making several prints from one single negative are all based on projecting light through transparent negatives onto unexposed film to make a print. The camera negative is then the **original**, and the prints are the copies made for viewing.

3.3 FLEXIBLE, TRANSPARENT MEDIA

3.3.1 Glass

The first medium was metal plates, but the need for stable, transparent materials resistant to chemical compounds resulted in the use of glass and paper coated with various substances.

Glass is a material possessing good optical properties and is reasonably inexpensive, but is fragile, stiff and heavy. Although glass would continue to be used well into the twentieth century, it could never used for motion pictures.

3.3.2 Cellulose nitrate

Cellulose nitrate was discovered in 1846 as the result of nitrating a cellulose solution in the presence of sulphuric acid. It is highly explosive, and is unstable and unreliable even as an explosive. Twenty years later, one improvement after the other led to a non-explosive derivative, pyroxilin, which had plastic properties when combined with camphor. Later different types of nitrocelluose (trinitrates) were developed which were very stable.

Celluloid, a brand name for plasticized cellulose nitrate, was the first man-made plastic. Possessing excellent mechanical properties and being flexible, Celluloid can be used in rolls, possesses a high degree of tensile strength and does not readily absorb moisture. When cold, it can be machined using cutting tools; and when heated, it can be moulded or shaped into very thin, uniform sheets by extrusion. In thick sheets, it is somewhat yellowish in colour, but in the thin sheets used in the film making industry (approx. 140 microns (μm) thick) is almost

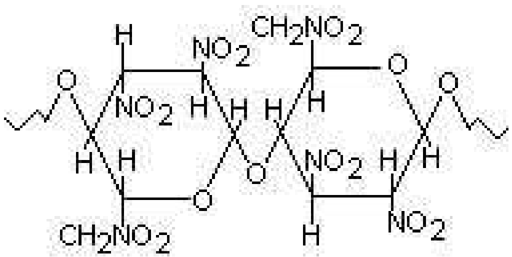


Figure 3.2 Molecular structure of cellulose nitrate

completely transparent, allowing nearly 95% white light to be transmitted.

In 1889, George Eastman incorporated Celluloid into his 'Kodak' photography system as a film base and, one year later, Eastman and Dickson set out on the collaboration that would result in the film used in Edison's 'Kinetograph' being made of Celluloid.

Cellulose nitrate, developed from research aimed at designing new explosives, still possesses a major degree of the chemical instability typical of these materials. It is not in any way explosive, but this instability takes on several forms. Cellulose nitrate ignites at a temperature of solely 160°C and can even burst into flame on its own. This is thought to be due to this temperature being reached inside a film stored at over 40°C, when contraction causes the pressure between the wound loops of film to rise.

At relatively high temperatures and high degrees of relative humidity (RH), cellulose nitrate undergoes chemical breakdown, often called decay, the molecular bonds breaking apart freeing nitrate groups (NO_3) which will hasten the breakdown process. The film hardens, contracts and becomes brittle. Eventually, as the rate at which the molecules break apart increases, the plastic completely depolymerizes, turning into powder. Thousands of 'nitrate' films have already been lost forever as the result of fires or decay, and all film stock of this type will eventually self-destruct.

This flammability led to research aimed at finding alternative plastics to nitrate. The best results were achieved by acetylating instead of nitrating the cellulose solution.

3.3.3 Cellulose diacetate

Starting in 1923, this plastic was first used in the manufacture of film stock. Its optical and mechanical properties were comparable to those of nitrate. Its moisture absorbency, which was much greater than that of nitrate, unfortunately results in greater shrinkage, and it was relegated to the smaller gauges, for 16 mm and 9.5 mm home movies. Home movies were only possible, safely, with the introduction of diacetate film base.

In addition, films were also made with a mixture of acetate and other cellulose esters, notably propionate and butyrate, usually described as 'mixed estars'.

3.3.4 Cellulose triacetate

In 1941 a new acetate was devised – cellulose triacetate. It was stable enough to replace Celluloid. It does not spontaneously combust and is relatively inflammable.

Cellulose acetates are highly permeable to steam and to numerous gases, but this permeability reduces the degree of acetylating involved. Triacetate is the most stable acetate and, having a moisture-absorption index which is two to three times higher than nitrate, retains physical properties similar to those of nitrate and shows a greater degree of dimensional stability. Triacetate is slightly yellow in colour, but in thin layers, as used for film, this is not significant. It was initially much more expensive to make than nitrate. In 1942, film first began to be manufactured using acetate, and in about 1950, when the Celluloid production lines began closing down, all motion picture film stock started to be manufactured using acetates.

Cellulose triacetate has a flash point of 430°C. Its chemical combustion processes at temperatures below its flash point are slow, and the plasticizer most often used in its manufacture, 3-phenylphosphate, contributes to reducing the inflammability. However, in chemical terms, triacetate is unstable. Under high humidity and high temperature conditions, triacetate triggers a hydrolysis reaction in which the acetic groups (OAc) bond with hydrogen to form acetic acid (CH_3COOH), which acts as a catalyst of yet further hydrolysis. The structure of the molecular bonds is weakened and deformed to the point of

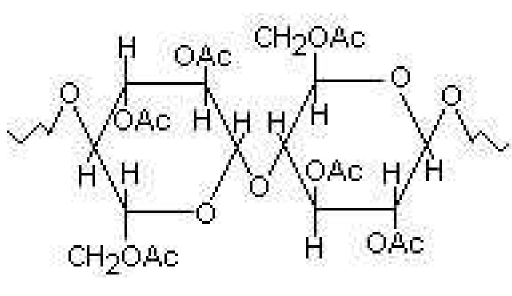


Figure 3.3 Molecular structure of cellulose triacetate

destroying their plastic properties. This 'vinegar syndrome', only recognized in the past 15 years, poses a serious threat to keeping this stock intact, particularly in warm, humid climates.

3.3.5 Polyester stock

Invented in the 1940s, polyester in its initial forms was of low transparency and photographic emulsions did not adhere to it easily, but by the late 1960s it was being widely used in the manufacture of magnetic stock and for Super 8 mm film. Polyester is now being used in all types of raw stock, and in the next few years will become more common for all films.

Its great breaking strength comprised another drawback for its acceptance in industry. For 35 mm or 16 mm motion pictures, if the film gets caught in the projectors, the machine shafts and moving parts can be damaged by the tensile strength of this film material. This plastic also has a tendency to build up static electricity. Polyester is dimensionally highly stable (and requires no plasticizers). Like triacetate, is not self-igniting, its flashpoint being approximately 480°C. Polyester's high degree of resistance to industrial solvents and acids has made it necessary to develop heat-welding systems for splicing purposes. In the future new forms of polyester are expected that will reduce some of its current drawbacks.

3.3.6 Comparison of nitrate, triacetate and polyester properties (see below)

3.4 LENSES AND LENS ASSEMBLIES

For contact printing, the surface of the negative comes into direct contact with the raw emulsion. Light is transmitted by the original negative to produce an exact image. The first photographic images were also made this way as silhouettes of leaves. If the object is not in good contact with the emulsion, selection and focusing of the rays of light is required.

3.4.1 Pinhole camera lenses

The simplest focusing device possible is a small hole in the front of a 'camera obscura', which reduces the light, reflected from the object to a single directional beam. These pinhole stenoscopic cameras focus all objects equally, and have no changing depth of field, but definition is low and image brightness is low.

3.4.2 Lenses

A lens is a transparent, polished (or magnetic) device which is capable of changing the direction in which rays of light (or of electromagnetic energy) strike or pass through it.

The basic classification for almost all types of lenses relates to the deviation which they cause to a set of transmitted parallel rays. If the effect of the lens to shorten the spacing between the rays and concentrate brightness, they are referred to as converging lenses. Diverging lenses are those which may be considered to widen the space between the

	Tensile strength kg/cm^2	Ultimate stretch (%)	Tear resistance kg/cm^2	Moisture absorption 24 hours/20°	Gas permeability	Flammability	Acid and alkali resistance	Resistance to micro-organisms
Nitrate	680–750	30–40	—	1.5–2.0	High	Very high	Low	—
Triacetate	612–1088	10–40	3.7–26.9	3.5–4.5	High	Low	Low	Dependent on plasticizer
Polyester	1160–1700	70–130	33.7	0.8 (16 h/25°C)	Very low	Very low	No attack	Very good

rays, dispersing the light and reducing brightness. Lenses are usually symmetrical, and when a parallel beam of light is transmitted, it is concentrated at (or appears to diverge from) a **focal point**.

For converging (or positive) lenses, the focal point is an actual, physical point located in front of the lens. For diverging (negative) lenses, the focal point is a virtual point and is located behind the lens. The lenses most often used are spherical lenses, the working surfaces of which are ground into the shape of a segment of a sphere. Spherical mirror lenses and cylindrical lenses and prisms are also used in motion picture photography.

3.4.3 Refraction and dispersion of lenses

Out in open space, light travels at the same speed for any wavelength, but when these waves flow through matter, their speed will vary depending upon their wavelength.

Light changes speed and direction when transmitted through the junctions of materials of different optical densities. This phenomenon, known as refraction, is defined numerically as a value which differs, is ascribed to a transparent material and relates to change in the speed of the light between one material and the next.

Water has a 1.33 refraction index, and glass within the range 1.45–1.95. The least dense glass, crown glass, has a refraction index of over 1.5, and high density flint glass, over 1.75.

When white light shines through a lens, the violet light waves undergo the greatest possible degree of deflection, the red light the least. The angle between red and violet is known as dispersion and, although it is related to the density of the lens material, it also depends on the chemical composition of the material.

For transparent lenses, the speed and direction of the light undergoes many different changes on entry, during transmission and on exiting. When transmitted through the surface, the speed is reduced as a function of the optical density (refraction index) of the lens. The direction of the light changes as a function of the angle of deflection which the light and the lens surface form. Secondly, individually for each wavelength, the speed at which the waves are transmitted by the glass depends on the chemical composition (the dispersion index). After transmission by the second surface, the light regains its initial speed, but changes direction once again, individually for each colour, depending upon the angle it makes with the surface through which it exits.

3.4.4 Aberrations

By deflecting and dispersing the light, lenses change images. The change in speed and the dispersion of light give rise to colour aberrations. The red image is larger (axial aberration) and is focused much further away from the lens than violet (longitudinal aberration), other colours forming images between the two.

Geometrical aberrations are caused by the shape of the lenses and by the angle at which light strikes each point on the lens surface.

Spherical aberration, when a lens is not perfectly spherical, shapes images progressively further away from the lens.

The aberration known as coma distorts the image in relationship to the distance between the line of sight and each point of the image on the lens.

Stigmatism distorts a circular focused image by turning it into an oval.

In 1733, C. Moor combined a converging crown glass lens providing a low degree of dispersion with a diverging flint glass lens providing a high degree of dispersion, and achieved an assembly which lowered the degree of chromatic aberration. The achromatic lens gave rise to the design of lens assemblies capable of correcting aberrations.

The image produced by each lens of an assembly has been modified by the previous lens and consecutive lenses are designed to correct the aberrations of the first. No lens exists which will cancel all of the various aberrations at the same time, and most lens assemblies are intended to correct the most damaging.

4

The film making industry

4.1 STROBOSCOPES AND CINÉMATOGRAPHE

Throughout the 1890s, a great many inventors demonstrated systems and equipment capable of recording (filming) the movement of real images in a series of consecutive photographs, and mechanically presenting the images to the viewer. The industry developed out of one of these systems (but not just the first).

4.1.1 The Kinetoscope

In August 1891, Thomas Edison registered the first patents for the Kinetoscope, a true film making apparatus which he presented to the public two years later. But the Kinetoscope worked on the same stroboscope-related principle as the Zoetrope and other similar inventions, using a strobe type viewing system which can be viewed by only one viewer at a time (or by a very small group of viewers).

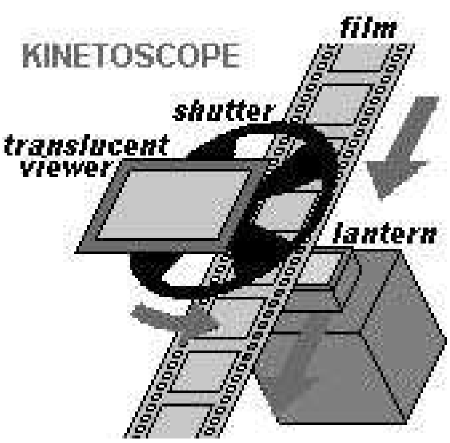


Figure 4.1 The Kinetoscope

In the Kinetoscope, the film is run in front of a light source (a projecting lantern) moving at a constant speed in front of the viewer, who sees it through the peepholes made in a round disc or shutter located between the viewer and the film. The disc revolves in the opposite direction to the film, creating a flickered field of view. The eye's persistence of vision, enables the viewer to retain each one of these segments in the form of a still image, which is immediately replaced by another image. The images blend together, giving the eye the sensation of continuous movement.

4.1.2 The Cinématographe

Motion picture film making commenced with a mechanical intermittent film transport system developed simultaneously by several inventors, but which was made popular and further refined by the Lumière Brothers. This system, which incorporated mechanical components originally designed and used for other purposes (i.e. in clocks and sewing machines), converted a circular motor action into an intermittent linear movement.

On 13 February 1895, the Lumière Brothers patented their Kinetoscope. This name was soon changed to the 'Cinématographe'. The first screening was held on 22 March, a private event, and on 28 December, the Lumière Cinématographe was triumphantly presented at a public gathering in Paris.

The Lumière system uses alternating intermittent movements for the transport of the film. This is synchronized with the movement of a revolving shutter which shuts out all light whenever the film is being transported. The images seen by the viewer are stationary at the time of viewing. The persistence of vision

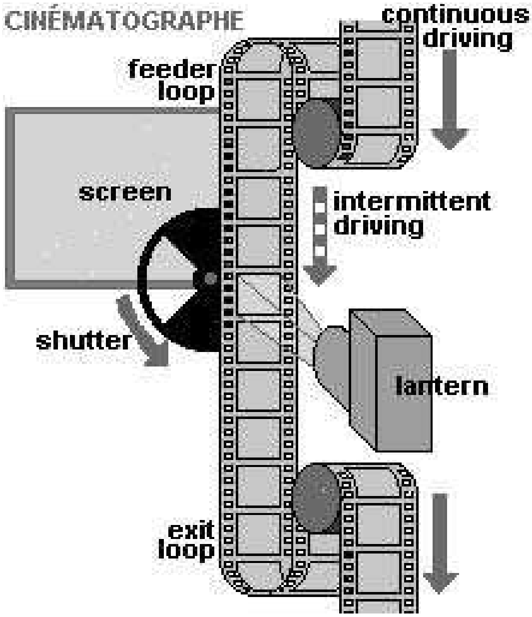


Figure 4.2 The Cinématographe

blends the image's in the mind's eye of the viewer. The same technology could be used for both camera and projector.

4.1.3 Film making and show business

The opportunity of showing a high quality moving picture to an entire audience enabled the motion picture industry to make a place for itself in the world of show business. The success of the Lumière Brothers' endeavours and their researches undeniably laid the 'cornerstone' of a new industry based on mass public screening system.

Once the Lumière and Edison principles had been combined, the mechanical screening of consecutively photographed images was a fully developed system, virtually identical to the system which is still in use today.

The fundamentals of the motion picture industry as they were both then and now are:

1. Motion pictures (films) were made on two film stocks: the original negative film and the print film (prints for release to the cinemas). The two types of film may differ from one another and are processed and handled differently today; they comprise a whole, being related to each other and designed to be used together. Damage to or the loss of either reduces the value of a film. Loss of both is loss of the film entirely. Initially these two films may have been very similar in character, but they quickly became specific to their purpose and acquired different properties.
2. The picture is comprised of a series of photographs capturing consecutive stages of the movement. These photographs are taken at a constant shutter speed and are screened at the same speed as they were filmed.
3. The film is a transparent plastic film base and a photographic emulsion of natural gelatines and light-sensitive silver salts adhered to the film base.
4. The film moves through both camera and projector in an intermittent manner, transported by means of teeth (called sprockets) on wheels or rollers. The sprockets engage with holes (perforations, or 'sprocket holes') in the film base. These sprockets and perforations define the synchronism between frame, camera shutter, printer gate and projector shutter throughout the entire shooting, laboratory processing and projection sequence.

4.2 FILM

Motion picture film, like other photographic materials, has two different layers – the film base and the emulsion – and usually they are held together by a special binding layer.

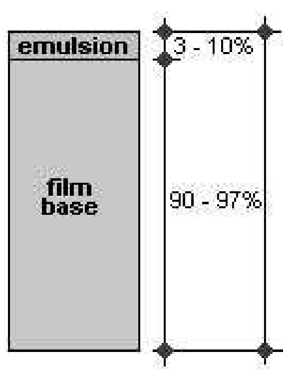


Figure 4.3 The structure of film in cross-section

A film should be uniform in thickness. However, between one manufacturer and another, or one film type and another, film thickness may vary, although most are between 120 to 145 microns (μm). The film base and the emulsion individually also differ greatly in thickness; the emulsion varies from 3% to 10% of the total thickness of the film. The triple-layer emulsions for colour are appreciably thicker than black and white emulsions.

A sandwich is mechanically unstable, even when the layers are made up of the same material. Stable 'sandwich' materials are usually an uneven number of layers (3, 5, 7) and are symmetrical. The opposite layers offset the stresses that the differences in humidity and temperature can create.

However photographic films are not symmetrical. The main layer, the film base, is stiff and is much less likely to give off or absorb moisture. The thinner of the two layers, the emulsion, is not as hard and gives off and absorbs moisture relatively easily. When the emulsion absorbs moisture, it therefore swells unevenly, and if the way it has been wound on the reel does not allow for expansion, it will be crushed or distorted by the increase in pressure. When moisture is lost, the emulsion shrinks, lowering the pressure between the loops of film and loosening the wound loops of film, making it easier for the film to lose its shape.

Absorption and release of moisture can be offset by corrective measures during storage, but once damage has been caused, it is permanent.

During the early years, while films were still less than 50 metres in length, there were no proper distribution channels or permanent screening establishments. Each film projectionist (often also the producer of part of the films being shown) adapted his apparatus to project whatever films he had, and even adapted the films to his apparatus. The further development of film making as a business was hindered by the differences between the physical dimensions of the films. Without some standards distribution and growth was limited. The industry was forced to standardize the dimensions and fundamental operating features of films.

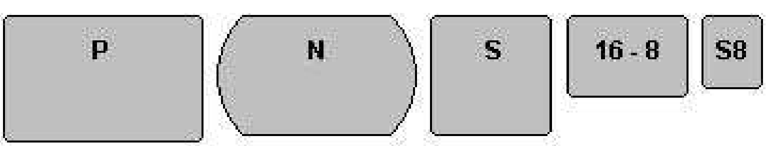
The principle dimensions that need to be standardized are width (also called gauge), sprocket hole dimensions (also called perforation) and the pitch (the distance between sprocket holes.

4.2.1 Sprocket holes and standards

The sprocket holes are the basic film transport device for both cameras and projectors, as well as for laboratory printing equipment.

Currently there are standards for 35 mm, 16 mm, 8 mm, 65 mm and 70 mm wide film. The standard stipulates the height and width of the sprocket holes, the radius of the curves at the corners, the distances to the edge of the film, and the alignment tolerances between two sprocket holes and the edges. The dimensions of the four sprocket holes on each edge of a 35 mm frame took many years to become standardized. There are two different types of sprocket holes currently in use.

Throughout almost the entire silent screen era, the size and shape of sprocket holes was defined by the film manufacturers, and sometimes by processing laboratories. The



P 35mm soundtrack negatives and prints 70mm films
N 35mm camera negatives and duplicating films
S 35mm standard-format 4-track scope prints
16-8 16mm & 8mm films
S8 S8mm films

	height	width	corner roll
P	1'98	2'80	0'50
N	1'85	Ø2'80	-----
S	1'85	1'98	0'33
16	1'27	1'83	0'25
S8	1'143	0'914	0'13

Figure 4.4 Film perforations

sprocket holes varied widely in size, were rectangular, round-cornered or right-angled, or had short, semicircular sides or were completely round.

4.2.2 35 mm film sprocket holes

The print which was finally accepted as the standard was designed by Kodak in 1923. This sprocket hole is known as the Kodak Standard (KS) or positive (P) sprocket hole. The sprocket hole for 35 mm negatives proposed by Bell and Howell was smaller and had rounded short sides. This sprocket hole is known as the negative (N) or Bell and Howell (BH) sprocket hole and became the negative standard.

By accepting two different sprocket holes for one film gauge, the industry was attempting to achieve longer life prints and the best possible stability in the positioning of negatives and dupes in cameras and printers. The positive print sprocket hole has a greater height than the negative, improving transport by rollers and the rounded corners reduce the risk of tears.

At conventions held in 1934 and 1936, an attempt was made to combine these two types, but the majority of the manufacturers opted to keep both. The Dubray–Howell (DH) sprocket hole, having the same height as that of the negative and straight sides like a print, was one of the most well accepted as a standard, but eventually fell into disuse.

For the prints of the first few motion pictures filmed in Cinemascope, a new, smaller sprocket hole was created which left enough room for the four magnetic sound tracks. This was the ‘S’ sprocket hole (also known as the Fox Hole): it is the same height at the negative and has a width of 1.98 mm.

4.2.3 Sprocket holes for other film gauges

Only 35 mm films have different sprocket holes for negative and positive films. Others use the same type of sprocket holes on prints and negatives.

On the 70 mm stock and on the 65 mm negatives, the (KS) print sprocket hole is used throughout. For the motion pictures filmed using this film size format, a single frame takes up a total of five sprocket holes, but spectacular screening systems which also use this stock, such as the Omnimax system, can take up to as many as 15 sprocket holes per frame.

Originally, the 16 mm stock was manufactured with a row of sprocket holes along each edge, but in order to make room for the optical soundtrack, the sprocket holes were removed from one edge. At present, 16 mm film for negatives is being manufactured with one or two rows of sprocket holes, and the stock for prints with one single edge having sprocket holes. Super 16 uses one sprocket hole and the image extends over the other sprocket hole position. Super 16 is either printed by magnification onto 35 mm film or used for television. If it is printed onto 16 mm film part of the image is lost.

The 8 mm film (sometimes called Double 8) employs the same type of sprocket holes as the 16 mm stock, while a new, smaller (1.143/0.914 mm) sprocket hole was designed for Super 8 films.

4.2.4 Pitch

The pitch is defined as the distance between the inside edges of two consecutive sprocket holes (the edges on which the gate-side claws are placed on feeding a film through cameras and projectors).

The pitch can vary from one film to another of the same size format depending upon the use for which they are intended.

Modern standard pitches

Film gauge	inches	mm
Standard 8	0.1500	3.810
Super 8	0.1667	4.234
16 mm long pitch	0.3000	7.60
16 mm short pitch	0.2994	7.605
35 mm long pitch	0.1870	4.75
35 mm short pitch	0.1866	4.74

4.2.5 Short and long pitch film stock

When high-speed, continuous contact printers started being used, the use of two different pitches (short and long) became necessary for print film stock. In these machines, the negative is printed by contact with the raw stock, emulsion to emulsion, on a toothed roller with a slot for the printing light. The driven roller transports both films, and the thickness of the negative (approx. 140 microns) on the inside of the curve causes the raw stock to take up a wider radius and longer path. If both films were of the same size, and driven by the same teeth, the outer raw stock would slip on the negative. When triacetate stock, which was much more rigid than Celluloid (which stretches slightly), first began to be used, it became necessary for the previously made suggestions for different pitches for negatives and prints to be accepted.

For intermittent printers, often called step printers, which fit the pull down claws into the sprocket holes before starting to move each frame, exposing one frame at a time, these differences in pitch are not necessary.

The pitch for 35 mm and 70 mm films is 4.74 mm (short pitch) and 4.75 mm (long pitch).

For 16 mm, the pitch is 7.605 and 7.620.

For 8 mm (Double 8) single pitch is 3.810 mm, and for Super 8 mm reversal, 4.234 mm.

4.2.6 Special perforations

If requested, raw stock manufacturers will often manufacture any of their film stocks with any of the standard perforations, and 35 mm and 32 mm stock is manufactured with perforations that allow two 16 mm or four 8 mm prints, side by side. The film is then slit after processing.

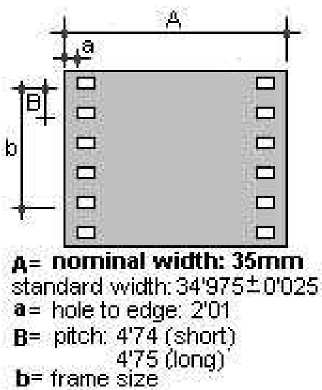


Figure 4.5 35 mm film

4.3 35 mm FILM STOCK

The joint efforts of W. Dickson and G. Eastman in inventing Edison's Kinetoscope led to the invention of perforated motion picture film. In turn, this led to the basic standards films 35 mm in width with four sprocket holes on each side of the frame and 16 frames per foot (304.8 mm) of film strip. (The Lumière Brothers also used 35 mm film and the 16-frame/foot arrangement, but they placed one single round hole on each side of each frame.)

Although it was not until 1916 (in the USA) that international standards began to be set to standardize the dimensions of 35 mm stock, 35 mm four-perforation holes per frame film was the most used format right from the start, both for filming and for making release prints.

4.4 16 mm AND 9.5 mm SIZE FORMAT STOCK

At almost exactly the same time in 1923, Kodak and Pathé presented new film stock formats for use, in principle, for home movies. In both cases, a safety base, cellulose diacetate, was used, a non inflammable base being much safer for the home user. These two new film stock formats were exactly the same: one sprocket hole per frame, with a 7.620 mm pitch and 40 frames per foot of film. Both were marketed with reversal films, which are developed directly to a positive image. The 16 mm picture quality as well the lightweight 16 mm equipment led to a ready acceptance on the part of professional film makers eventually as well, mainly for documentaries and

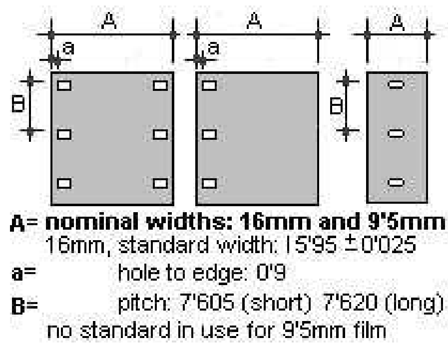


Figure 4.6 16 mm film and 9.5 mm film

news film, and television in the 1960s later used 16 mm film extensively.

The 9.5 mm film (also known as Pathé Baby) never made it beyond the home movie environment and was practically ousted from the market when 8 mm film was introduced. It had a smaller surface area than 16 mm when it was introduced and therefore a lower quality, but its principal drawback was mechanical, a result of the single, centrally located sprocket hole.

4.5 70 mm SIZE FORMAT STOCK

Almost from the very birth of motion pictures, larger gauges than 35 mm were used, but it was not until the 1960s that a standard 70 mm printing system with six magnetic soundtracks came into use. For filming, 75 mm or 65 mm gauges were used. From these negatives, it is possible to make smaller copies in 35 mm anamorphic. Later 70 mm prints from films shot on anamorphic 35 mm were made.

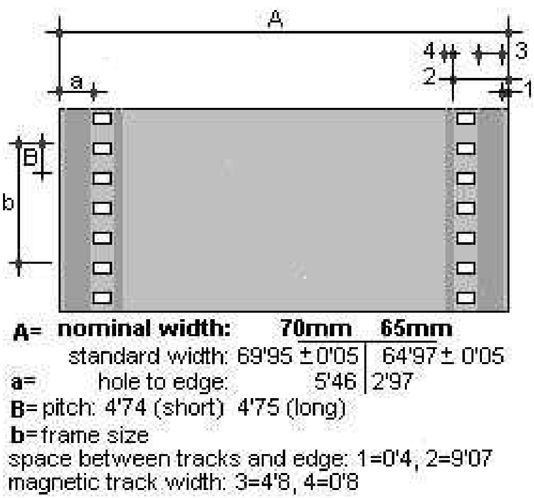


Figure 4.7 70 mm film

The screening systems for curved or superscope screens employ this type of stock. In some 70 mm systems (e.g. Imax), the motion picture is filmed and projected horizontally, and the frame takes up to 15 perforations (71.25 mm).

4.6 8 mm FILM STOCK

In 1933, when 16 mm stock started being used for professional film making, Kodak launched a new type of film for home movies – 8 mm film (or Double 8), which would be marketed worldwide and, in the 1950s, would become universal for making home movies.

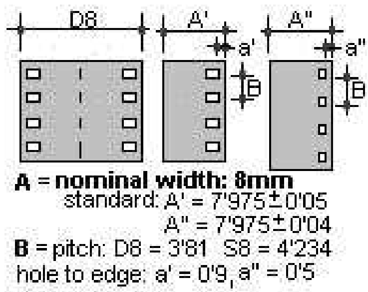


Figure 4.8 8 mm gauges

Double 8 film was manufactured on 16 mm stock perforated with twice the number of sprocket holes on each edge and reversal film emulsions, such as Kodachrome. The film was exposed in the camera down one side of the film, then reversed and exposed down the other side. After developing, the laboratory slit the roll along its lengthwise axis, obtaining two 8 mm strips which were spliced together to make one length.

The Super 8 and Single 8 formats were presented by Kodak and Fuj, respectively, in 1965. The main advantage lay in using a smaller perforation and therefore an image almost doubled that of Double 8 with a considerable increase in image quality. The 8 mm wide single strand film was supplied in a 'cartridge' or 'cassette' which made camera loading easier. When home video cameras came out, sales of this type of film vanished.

4.7 FILM PROJECTION

4.7.1 Frame rates

Except to create special effects, the number of frames projected per second must match the camera speed.

The human eye and its data reception and transmission system can form, transmit and analyse 10–12 images per second. The vision centre in the brain retains each individual image for one-fifteenth of a second. If the vision centre in the brain receives another image during this fifteenth of a second, the sight mechanisms will create the sensation of visual continuity.

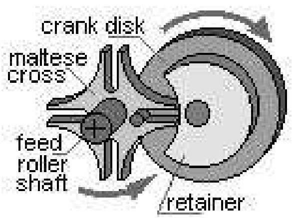


Figure 4.9 The Maltese Cross shutter

Both the two basic speeds employed throughout film making history (16 frames per second and 24 frames per second) adequately provide the requirements of visual continuity.

In laboratory testing, it has been found that the human sense of sight can distinguish up to 48 flashes of light per second, the switching from light to dark not being detected when they take place at higher rates of speed. Therefore, for example, the flickering of lamps operating on alternating current at 50 cycles per second is not visible to the human eye. At slower rates of speeds (i.e. 16–24 times per second), the changes in brightness are perceived as flicker, which becomes more distracting the greater the brightness of the flash.

4.7.2 Feed and shutter synchronization

In the Maltese Cross system, the system most used for projectors, the wheel which transfers the impulse to the film transport system (the crank disk) must make one full turn to move the Maltese Cross once. The Cross is connected to a sprocket wheel which revolves by one-quarter turns (corresponding to four sprocket holes) which transport one frame the distance of one frame. During this film movement, the shutter, which is synchronized with the crank disk, shuts out the projector light. The combination of these mechanisms, persistence of vision, and a sufficient frame rate enables the sequence of still images to be perceived as continuous motion.

4.7.3 Silent film shutter and screening speeds

To achieve visual continuity, the shutter need open and close the aperture once per frame (using a single bladed shutter). At the speed of silent movies, this means that the screen is lit and goes dark 16 times per second. As the Lumière Brothers and others must have discovered from the start, the picture on the screen flickers intolerably at this rate. Using a dual blade shutter doubles the number of interruptions and provides a better (but not perfect) effect. Later, theatres equipped with large screens and high-powered projector arc lamps made the shutter flicker even worse, and it became necessary to use triple-blade shutters (one of the blades of which was to cover a 90° angle that concealed the film transport). Alternatively the frame rate must be increased.

A triple-blade shutter shuts out at least 54% of the projector light and requires greater precision than single or double shutters. There was also a need to make the projector arcs more powerful so as to show to larger audiences. Throughout the entire silent screen era no real consensus of opinion was reached over filming and screening speeds.

Generally speaking, films were shot at a rate of 16 images per second and were screened at whatever speed the cinema management chose. A number of films were intended to be shown at higher frame rates.

After 1930 and the introduction of sound tracks, 24 frames/sec became the norm. At this rate flicker with double-bladed shutters is not noticeable, although modern systems are equipped with three-bladed shutters to provide for better light continuity.

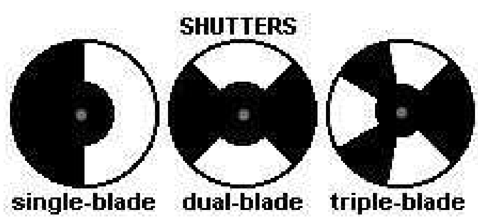


Figure 4.10 Single-, double- and triple-bladed projector shutters

5

Talking motion pictures

The arrival of sound around the end of the 1920s as an addition to motion pictures had an impact on every aspect of film making technology. It was necessary for the screening speed to be standardized, required changes to the screening format, the negative editing systems and printing systems, and caused tinting, toning and stencil colour systems to vanish. The image was always the main feature, and sound has always retained a subordinate position.

5.1 SILENT SCREEN ERA SOUND

From the start, motion pictures had always aspired to have sound. Although the industry waited 30 years before a true motion picture sound system came into being, films never actually did without sound. The negatives were silent, but cinema projection and display had sound.

Distributors and producers competed with one another to employ resources from the theatre. Sound varied from the presenter/narrator/commentator type, a piano, a group of orchestra musicians, with choruses, to soloists singing from sheet music composed expressly for the film. All of the resources of music-hall and comic opera were used to accompany screenings, including the creating of 'live' sound effects and, in some countries, the live dubbing of voices by groups of actors. In practice, the only limits placed on the media employed for this sound accompaniment lay solely in the producer's and exhibitor's financial means and the standing of the cinema.

A film creates an illusion of reality using the mechanical reproduction of moving images. Adding sound to the screening of silent films was in conflict with the state of the art, and the state of the technology, at that time. In theory, the same film could be viewed every day in any theatre, but the accompanying sound depended upon the theatre involved, on the musicians/singers/actors and could be different every day. Silent films and their accompanying sound were two completely different and separate realms as far as their aesthetics were concerned.

The consequences of the arrival of sound as an integral part of a film were disastrous for the preservation of silent film. When talking motion pictures first came out around 1927, and certainly from 1930, the public no longer wanted to have anything to do with silent films.

5.2 PROJECTION SPEED

5.2.1 Intermittent picture and continuous sound

Motion pictures make use of the fact that human perception of vision allows intermittent images to appear as if they were continuous. The human perception of sound has no such equivalent and sound must be presented to the sense of hearing as a continuous sensation. The mechanism that projects images therefore operates at a standard number of stationary images (frames) per second, whereas any presentation of sound must flow from the medium as a continuous flow. At the same time, if the film is to contain both image and sound the running speed of both must be the same.

5.2.2 One single, constant speed

In principle, except when attempting to create certain effects, sounds and images must be reproduced at the same speed at which they were recorded/filmed. In the silent screen era, there was no effort made to maintain the same speed throughout filming and screening (and when sound required that the running speed be increased silent films were normally screened at this increased speed).

The characteristics of sight mean that film images shown at an incorrect speed are still intelligible, and even film run backwards is still intelligible as time running backwards. Sound cannot be heard in the same way and changes in speed mean profound changes in frequency, or tone, and a lack of perceived reality.

A change in tone and harmony resulting from a change of just three frames per second in the speed of projection is unacceptable to the human ear. If the film direction is reversed the sound becomes unintelligible.

Musical frequencies on the diatonic scale – piano keyboard, key of C							
Middle C	D	E	F	G	A	B	C*
264	297	330	352	396	440	495	528
On speeding up the playback rate from, for example, 26 to 36 images per second (equivalent to showing silent films at 24 i/s), a 330-cycle (an E) would sound like a 495-cycle (a B).							

5.2.3 Separate recording and reproduction

All sound reproduction systems have built-in mechanisms for ensuring that recording and playback are done at the same, constant speeds.

In film making, it is additionally necessary for the image and sound speeds to be totally synchronized (colloquially said to be ‘in sync’) or exactly the same. Except in some specialized motion picture cameras (invented mainly for filming newsreels) and in many video cameras, the picture-filming equipment and the sound-recording equipment are separate from one another, although they function synchronously.

From the earliest Kinetoscope and disc synchronized projectors to modern projectors and video tape players, the picture and sound heads are mounted in the form of one single assembly equipped in order to ensure image and sound are at the same speed and synchronized.

5.2.4 Projector speed for talking motion pictures

Sound film was standardized at 24 frames per second. By using double-blade shutters this solved the problem of flicker and increased the film length by 50% for the same running time. It was inevitable that this rise in price would meet with approval.

Twenty-four frames (equivalent to 456 mm/second) was the minimum length necessary for reproducing an optical sound track capable of recording and reproducing frequencies up to 5000 cycles per second, which was considered necessary to obtain realistic sound reproduction quality. Thus it was essential to modify all filming and screening equipment and their motors to change their running speed. Hand cranking a camera was no longer able to provide acceptable sound and became a thing of the past.

5.3 COMPONENTS OF MOTION PICTURE SOUND SYSTEMS

5.3.1 Amplifying

A sound reproduction system must be *powerful* enough to fill the space of the cinema, and as the volume increases the amplifier must be capable of providing the volume without excessive distortion. The motion picture industry is mass entertainment; the movie theatres grew constantly larger and, by the late 1920s, any sound system for use in a cinema had to be capable of filling several thousand cubic metres.

5.3.2 Electronic tubes

In 1883, Edison discovered that, inside the glass tube of a lamp, an electric current flows from the filament to a separate wire, bridging the gap between the two. Twenty years later, it was found that a flow of electrons took place between the filament and the receiving wire. J.A. Fleming, also working with Edison's tubes, replaced the receiving wire with a plate (larger than the filament), to discover that the flow of electrons took place when the plate was positively charged, and that this flow halted when the plate was negatively charged. This is the basis of a rectifier that transforms an alternating current into a direct current.

In 1907, Lee de Forest started to work with these rectifier tubes and placed a perforated plate between the filament and the plate. This triode gave rise to a surprising effect of increasing the intensity of the flow of electrons, i.e. the voltage, fivefold. During research into broadcasting, in 1919, de Forest finally built amplifiers capable of providing enough power to fill a large movie theatre with sound.

5.3.3 From head-on listening to stereophonic sound

In the early days of talking motion pictures and for many years thereafter, the image was two-dimensional and sound was monophonic, a single speaker being installed behind the screen, requiring just one single soundtrack. In 1953, Cinemascope with stereophonic sound made its debut, incorporating four magnetic soundtracks. This was followed by Todd-AO for 70 mm films and the first 'stereo' systems on optical tracks. However, in all these systems the speakers were still positioned behind the screen.

In the 1970s and 1980s, systems were researched to incorporate side speakers and produce surround-sound. Although these systems are now capable of providing an absolutely real sound space, the two-dimensional quality of the picture on the screen placed in front of the viewer continues to condition the development of these systems. Generally speaking, with the exception of the films using large-format 3D systems, sounds to the sides and rear of the viewer continue to be used for reproducing effects rather than principle sounds.

5.3.4 Synchronization

Throughout their development, motion picture sound systems have always had to meet one specification; to ensure that the sound would be heard in complete synchronism with the picture. The Lumière system, using an intermittent film, made it difficult to synchronize picture and sound, and to keep them in sync. Initially discs and cylinders were used to provide the sound track, but in the celluloid film-strips the punched sprockets were often damaged and sections of film were lost. The moment this had happened, the picture and sound were no longer synchronized.

The incorporation of the sound tracks onto the same film strips as the picture solved this problem once and for all. Now, if a section of the film was damaged and lost the track was lost also, but the remaining film still had a synchronized image and sound track.

New disc-based digital sound systems have been being marketed, but in these devices the disc-scanning mechanism is controlled from a signal track located on the film strip.

5.3.5 Sound/image "advance"

Two 'heads' on one same reproduction system, one in front of the other, means that there is a gap (called the advance) between the image and sound recordings for each given point in time. Originally, each early system located the sound on the film as it best saw fit. So, the Phonofilm positioned the sound behind the image (approx. 14 frames behind), with the sound reader above the projector gate.

Eventually an approved standard placed the sound track ahead of the matching picture (by 21 frames) and the sound head beneath the projector gate. This standardization is not totally rigid, shifting in position of up to 2 sprocket holes on the prints currently meeting with acceptance. In some cases (for prints to be screened in very long theatres), somewhat shorter delays have been used to offset the length of time that the sound requires to travel throughout the theatre from the screen speakers.

For 16 mm films, a 26-frame advance for opticals tracks is used. On the magnetic tracks, the sound lags behind the image, positioned 28 frames behind it in 35 mm and 16 mm, and 24 frames behind in 70 mm films.

5.4 OPTICAL (OR PHOTOGRAPHIC) SOUND

Optical motion picture sound was a clever solution to the problem of incorporating a totally new signal into the existing system, using the least possible number of changes. The sound was recorded and reproduced as an image and was photographed, developed, edited and printed using procedures similar to those used for the rest of the images until the arrival of magnetic recording tape in 1953.

5.4.1 Recording and reproduction – 'photographing sound'

Sound waves are picked up by a microphone, where they are translated into an electrical signal. The signal is modulated proportional to the amplitude and frequency of the sound. The intensity of this electric current is amplified to the power necessary to create movement in either mechanical or magnetic devices that modulate the intensity, the direction, or the width, of a beam of light. The beam of light, focused by means of a microlens, exposes a narrow band on a photographic film moving at a constant speed (456 mm/second). The image is a series of 'spots' of light which reproduce the intensities and frequencies of the original sound in terms of density or width and in their rate of change. As the film is travelling the spots are transposed into bands of exposure. The film is then developed and fixed. This film image is the sound negative, in a linear image, of the modulation of the light to which it has been exposed.

5.4.2 Turning light into sound

The reproduction system is likewise simple. The sound negative is printed onto the image film. During projection, a beam of light of a constant intensity is directed through a microlens which focuses it onto the sound track of the film running at the same constant speed as during recording. The fluctuations in the density of the soundtrack will modulate the amount of light which shines through it onto a photoelectric cell positioned on the opposite side of the film. In response to the light to which it is exposed, this cell creates a flow of electrons (i.e. an electric current) which, after being suitably amplified, is routed to the speaker behind the screen.

5.4.3 Sound systems

All of the patents and processes employed for optical sound can be broken down into three major groups: variable-density systems (fixed area width), variable area systems (fixed density) and digital systems.

Both the variable-density as well as the variable-area systems are analogue systems, and their fluctuations in density along the length of the track are a response to the original sound. In the variable-density systems (Figure 5.2b), the photographic density is uniform over the full width of the sound track, but varies along its length. In the variable area systems (Figure 5.2a), the sound track is constant in density and each track is divided into two areas, one on each side of the track, one of which is theoretically opaque and the other transparent, and the relative width of these areas varies lengthwise.

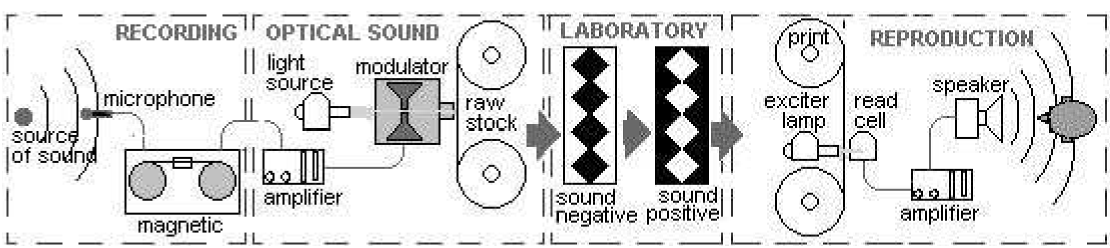


Figure 5.1 The photographic sound system

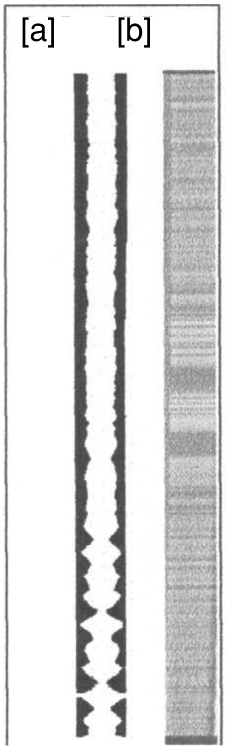


Figure 5.2 (*a*) A variable area sound track. (*b*) A variable density sound track

The number of sound track images varies depending upon the patented system. There are single-track and dual-track systems and even systems of up to 13 identical tracks. In the 1980s, stereophonic systems equipped with two separate tracks were marketed for the first time.

In digital stereophonic systems, the image encodes (as a graphic display) the binary data which will be converted into a sound signal by a scanning device, and most digital tracks have a mosaic of dot-like images. The optical signal incorporated into the film in the disk-based systems contains a code which controls the movement of the disk reproducer.

5.4.4 Compatibility

Once the track dimensions and advances and lags were standardized, most patents and systems have been made strictly compatible and are reproduced using the same systems. Some reproduction systems are fitted with sensors that detect the design features of the tracks and decide which standard system to use – standard optical, digital, stereo etc., and some modern tracks incorporate several sound systems by combining an analogue system with one or more digital systems.

5.5 MAGNETIC SOUND

5.5.1 Magnetism and electricity

Although magnetism is a property common to all atoms, in most materials, the magnetic regions of the minute magnets in atoms aligned in random directions, almost totally cancel out the material's magnetic properties. Iron, nickel, cobalt and some other (ferromagnetic) materials possess the property, in the presence of another magnetic field, of being able to realign their atomic magnets in a certain direction and, to a certain extent, to keep them pointing in that direction permanently.

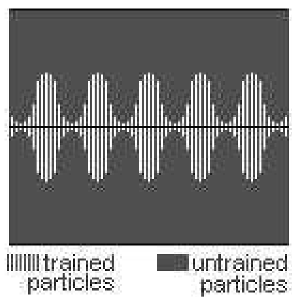


Figure 5.3 A pictorial representation of a magnetic sound track

This material shows magnetic polarization and exhibits all the properties of a magnet. In 1831, in an important and far-reaching scientific experiment, Michael Faraday discovered that an electric current in a coiled wire around one section of an iron ring creates a moving magnetic field. This field generated a flow of electricity in another wire wound on another part of the ring. Similarly, a permanent magnet inside a coil of wire generates an electric current in the wire when the magnet is moved. This is the basis of electromechanical devices such as motors and dynamos.

5.5.2 Systems and media

The first attempt to create sound reproduction was in 1881, but it was Valdemar Poulsen who first achieved efficient wire recordings, in 1896–1903. During the Second World War, German engineers invented a system which functioned on paper tapes coated in metal oxides. Later, plastic (acetate, PVC and polyester) tapes were used with one side coated with metal oxides, or metals.

Magnetic stock was used in 35 mm and 16 mm perforated film formats, or in unperforated films for reel-to-reel recording, but today in cartridges (cassettes). The first stereophonic anamorphic system used magnetic tracks on 35 mm prints. Magnetic sound tracks were also used on 70 mm, 16 mm and 8 mm prints, and especially on 16 mm camera news films in the 1960s and 1970s.

5.5.3 Magnetic sound recording

The sound waves are picked up by a microphone which creates a modulation (proportional in intensity and frequency of the original sound) of an electrical signal. This electric current is amplified to power the recording head, an electromagnet, past which the film with a magnetically neutral emulsion runs. The changes in the electrical magnet orientate the metallic particles of the emulsion in the same direction (to a greater or lesser degree depending upon the intensity of the signal) and the resulting track of aligned particles comprise an analogue magnetic representation of the intensities of the original sound modulation.

In order to reproduce the signal, the magnetic track is run (at the same speed as the recording speed) past an electromagnet. The fluctuations in the magnetic field create electrical fields in the electromagnet, the resulting current is amplified, and the signal routed to the speakers to reproduce the sounds.

Digital systems, which entered the market in the 1980s, are basically the same, but the signal is recorded by means of coded pulses which can be copied without error, and make it possible to vary and control the intensities and frequencies, and make many more sophisticated variations of the signal, usually called **digital sound restoration**.

5.6 IMAGE AND SOUND AREA – PROJECTION FORMATS

Although the image area and projection format concepts are frequently confused, they are two different aspects. The **image area** is the surface area of the film used to record the image; and the **projection format** refers to the dimensions and proportions of the image on the screen.

5.6.1 Image area (sometimes called the camera aperture)

The dimensions of the filmed image area are always slightly larger than those of the image actually projected or viewed (to avoid an image edge showing on the screen). The differences between these two areas are not limited to these alone. Various anamorphic and flat widescreen print systems may originate from quite different negative stock sizes and image areas. There are 70 mm flat wide screen, or 35 mm anamorphic or flat prints, which are made from a wide range of negative gauges and formats; from 65 mm or 70 mm negatives or blown up (magnified) from 35 mm or Super 35 or Super 16.

The relationship between the image area filmed in negative, and that which is reproduced on the prints, and the format shown on the screen will all depend upon:

- the lenses used during shooting
- the aperture exposed in the camera
- the lenses used during printing
- the aperture exposed in printing
- the lenses used during screening
- the aperture used in the projector
- the screen masking in the theatre.

5.6.2 Sound area

The area at the side of the image in which the sound track is printed is the sound reserve area. This is from the edge of the sprocket holes to the image area. The sound track is the sound track image area itself, the area scanned by the sound heads is slightly wider than the sound track image area.

5.6.3 Screening format (projector aperture)

To prevent the actual edges of the image area from being seen on the screen, which are often ragged and not absolutely straight, the area photographed on a negative and reproduced on the print is slightly larger than that shown on the screen in the cinema. International standards now exist to define the dimensions of the projected image, taking into consideration the dimensions and the aperture of the masks of the projectors which control the area of the beam of light of the projector.

5.7 35 mm IMAGE AREAS AND STANDARD FORMATS

5.7.1 Silent film or 'full-aperture' format

In silent films, the image filmed in each frame filled the entire surface area between the rows of sprocket holes and the junctions between the images of the consecutive frames. It is generally accepted that the area set aside for the image was 24 mm × 18 mm in the silent screen era and the optical centre was at the axes of the frame. The lack of standardization, and the hand-crafted basis on which most of the manufacturers of motion picture cameras worked, gave rise to a situation in which absolute freedom of choice was possible, and where the height and width of the frame could vary from one camera to the next. There was no fundamental component for the motion picture business, and the screened image area was never defined.

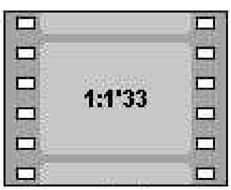


Figure 5.4 The full aperture 1.33:1, 24 mm × 18 mm

Nevertheless, in the silent screen era, an aesthetic criterion came into being regarding the screening format based on a screen image height to width ratio of 1:1.33 proportion. In the past 20 or 30 years, shooting with a full-aperture image, which uses the entire area between sprocket holes for the frame on the negative has returned and is known as Super 35 mm. This can be printed by anamorphic compression or by enlargement, in individual shots or sequences, or cut to any desired format.

5.7.2 The sound area

Along with the standardization of the screening speed, the major technical impact of the adding of sound to film was standardized reduction of the area devoted to the image on films.

The positioning of the sound area next to one of the rows of sprocket holes made it necessary to shift the position of axis of the image horizontally, and to reduce its area. The sound area takes up the space between the image and sprocket holes and takes up a total width of approximately 3 mm. The theoretical 24 mm of the silent film format width was therefore reduced to approximately 22 mm. (If the height stayed the same the new aspect ratio would be 18 mm × 22 mm, or 1:1.22). The industry, placing priority on keeping the proportions (1:1.33) the same, agreed to cut down the area of the image area even further, enlarging the space between consecutive frames.

5.7.3 'Academy' or standard format

In principle, the new sound image area continued to have the same aspect ratio of 1:1.33 of silent films or thereabouts. Eventually, a standard ratio called Academy (the Academy of Motion Picture Arts and Sciences, of Hollywood), also called the Movietone area, won the day. This measures 16.03 mm in height by 22.05 mm in width, an aspect ratio to 1:1.37.

The projection format issue is still not resolved and strangely this format is still not a key issue. The ISO Standard differs slightly in dimension (16.00/21.95 mm), but has the same aspect ratio!

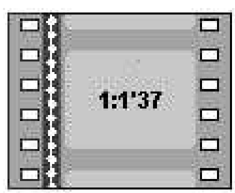


Figure 5.5 The Academy image

5.7.4 Widescreen formats

The efforts made to make motion pictures more visually spectacular led to the development of formats, film gauges and entire filming and screening systems which revolved around enlarging the size of the screen and the quality of the image. In the systems based on the screening of one single 35 mm film, two different techniques were developed.

'Scope' or anamorphic formats

The anamorphic systems are based on the filming of the image by changing its aspect ratio optically in one plane more than another. One approved standard is in keeping with the Cinemascope compression criteria, using lenses (which are normally cylinder lenses) to achieve a compression ratio (enlargement ratio for screening of '×2'. That is to say that the horizontal dimension is 'squeezed' optically while retaining a normal vertical image. The 'scope' squeezed frame is standardized at 18.16/21.3 mm, a negative image ratio of 1:1.17, with an aspect ratio on projection on the screen of 1:2.34.

Other anamorphic systems employ different schemes for filming and for making prints. In Technirama (perhaps the optimum system for anamorphic images), the negative was shot on 35 mm film which was run horizontally through the camera, creating frames having eight sprocket holes. The image was put through two anamorphic processes (first during shooting and second on making prints), leading to the same total compression (×2) and being projected with standard de-anamorphizing projector lenses.

Finer-grained colour emulsions put on the market in the 1960s made possible the invention of systems that used only two sprocket holes for the height for each frame. In Techniscope, the negative was filmed using modified cameras and standard lenses. The prints were made optically enlarged to four sprocket holes high with anamorphic compression. This was a very inexpensive anamorphic process.

Flat 35 mm widescreen formats

The success of anamorphic (often loosely called 'scope', after Cinemascope, the first) formats boosted the launching of flat widescreen scope formats filmed using conventional lenses. In these the space between frames is enlarged even further and a major part of the emulsion-coated surface of the film was not used to full advantage, and these were sometimes called, in a derogatory manner, **letter box** formats. Three of these formats have become popular on a wide-ranging basis under several different names. Their screen aspect ratios are: 1:1.66; 1:1.75 and 1:1.85.

Another 35 mm development was Vistavision, where the frame took up eight sprocket holes horizontally, and the negative and the positive were the same. This system met with failure due to the need of redesign projectors to run the film horizontally and move eight sprocket holes per frame.

Other scope formats

The 70 mm film width affords the possibility of filming in scope format using normal lens assemblies achieving extremely high quality images. The ISO Standard, defines the projected frame as 22.10 mm/48.59 mm with a 1:2.20 aspect ratio.

Super 35 mm (total aperture) using anamorphic lenses is often used as the camera stock, to make copies in 35 mm anamorphic or in 70 mm flat format.

Super 16 mm format negatives, where the image field extends into the sound field on the prints, is not used to produce a wide screen 16 mm print. These negatives (flat format negatives) are usually blown up to 35 mm anamorphic format at 1:1.66, or are cropped to make a standard 16 mm print.

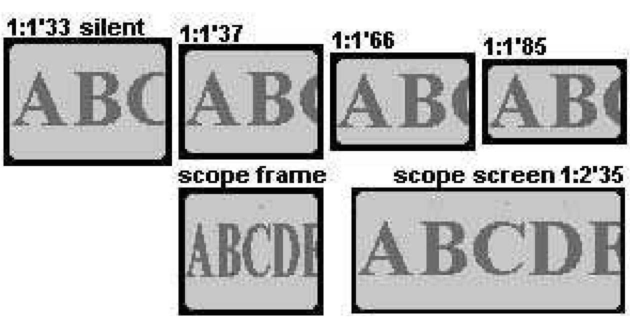


Figure 5.6 Frames and formats

5.8 IMAGE AREA, FORMAT DIMENSIONS AND ASPECT RATIOS

The measurements given here have been taken from the ASA and ISO Standards. These two standards differ to a minor degree. Note that the decimal point is shown here as a comma (,) in the continental manner.

FORMAT AND NOMINAL ASPECT RATIO		CAMERA			SCREENING	
		Distance to reference edge (mm)		Surface area of image filmed (mm)	Surface area of image screened (mm)	Aspect ratio: 1
35 mm						
Silent (1)	1,33	—	—	18,00/24,00	17,25/23,00	1,33
Normal (2) (a)	1,37	(b)	18,75	16,03/22,05	15,25/20,96	1,37
Normal (3)	1,37	(c)	7,80	16,00/21,95	15,29/21,11	1,37
35 mm (wide screen) (2)						
	1,85	(b)	18,75	(4)/22,05	11,33/20,96	1,85
	1,75	(b)	18,75	(4)/22,05	11,96/20,96	1,75
	1,66	(b)	18,75	(4)/22,05	12,62/20,96	1,66
	(3) 1,85	(c)	7,80	(4)/21,95	11,33/21,11	1,86
	1,75	(c)	7,80	(4)/21,95	11,96/21,11	1,76
	1,66	(c)	7,80	(4)/21,95	12,62/21,11	1,67
Vistavisión (5)	1,75	—	—	22,10/37,52	21,31/37,29	1,75
Cinerama (6)	—	—	—	—	27,64/75,06	2,71
Cinemascope (S. mag.) (2)	2,55	(b)	17,50	18,67/3,80	18,16/23,16	(d) 2,55
Cinemascope (S. opt.) (2)	2,35	(b)	18,75	18,67/22,10	8,16/21,31	(d) 2,34
'Scope' (3)	2,35	(c)	7,80	18,60/21,95	18,21/21,29	(d) 2,34
Technirama (5)	2,35	—	—	23,80/37,15	18,16/21,31	(e) 2,34
Techniscope (5)	2,35	—	—	9,34/22,10	18,16/21,31	(f) 2,34
16 mm						
	(2) 1,33	(b)	7,97	7,49/10,26	7,21/9,65	1,33
	(3) (g) 1,33	(c)	2,95	7,42/10,05	7,26/9,65	1,32
S16 mm	(3) (h) 1,66	(c)	2,95	7,42/12,52	—	—
70 mm						
65 mm (3)	2,20	(c)	6,24	23,00/52,50	—	—
70 mm (2)	2,20	(b)	34,95	23,00/52,60	22,00/48,60	2,21
70 mm (3)	2,20	(c)	8,73	23,00/52,50	22,10/48,59	2,20

Notes: (1) Dimensions never standardized. (2) ASA. (3) ISO. (4) Dimension never standardized for negative. (5) Dimensions never standardized. (6) Cinerama on three films projected as a panorama (plus a fourth base for the eight sound tracks). The image was incorporated in three frames of 27.64/25.07 (on 5 sprocket holes). The projection format (1:2.71) 'masked' by the curvature of the screen which cut the perception of the proportions to 1:2.2.

(a) Dimensions were standardized for negatives and prints as the 'Movietone' format, aspect ratio 1:1.37. (b) Between edge of reference and the axis of the image field. (c) Between edge of reference and edge of image field. (d) De-anamorphized (unsqueezed) image on screen. (e) De-anamorphized (unsqueezed) image on screen. (f) De-anamorphized (unsqueezed) image on screen. (g) The dimension given is only as a guide. (h) 16 mm 'W' type.

5.9 SOUND TRACK DIMENSIONS

Measurements are taken from the Standards issued by the International Standard Organization (ISO).

SIZE FORMAT AND SYSTEM		Axis to edge of reference (mm)	Sound area width (mm)	Sound track width (mm)	Scanned area (mm)
35 mm	Variable area	6,30	2,99	1,93	2,13
	Variable density	6,30	2,99	2,54	2,13
Scope magnétic (a)					
	Track 1	1,02		1,60	1,27
	Track 2	5,36		1,60	1,27
	Track 3	20,18		0,97	0,635
	Track 4	33,99		1,60	1,27
35 mm sep-mag, 3 tracks					
	Track 1	8,60		5,00	
	Track 2	17,50		5,00	
	Track 3	26,40		5,00	
35 mm sep-mag, 4 tracks					
	Track 1	7,90		3,80	
	Track 2	14,30		3,80	
	Track 3	20,70		3,80	
	Track 4	27,10		3,80	
16 mm	Variable area	1,48	2,95	1,52	1,80
	Variable density	1,48	2,95	2,03	1,80
	Magnétic (1)	14,55	2,95	2,55	2,15 (2 tracks)
70 mm Magnétic (b)	Track 1	1,42		4,80 (3 tracks)	1,25
	Track 2	4,22			1,25
	Track 3	9,47		0,80	1,25
	Track 4	60,52		0,80	1,25
	Track 5	65,77			1,25
	Track 6	68,5		4,80 (3 tracks)	1,25
8 mm	Magnétic	0,40	0,90	0,67	0,48 (2 tracks)
Super 8	Optic	7,57		0,50 (4 tracks)	0,66
	Magnétic (1)	7,58		0,68	0,53 (2 tracks)

Notes: (1) The 16 mm and S8 format films with magnetic sound may have another track on the opposite side to ensure uniform winding. This track, located between the sprocket holes and the edge, is not used for recording sound. (2) Head gap or universal dimension. (3) Sound tracks 1–2 and 5–6 are on the same magnetic stripe. (4) Modulated area width. The recorded field can be up to 0.75 in width.

(a) Relationship of tracks to speakers in theatre: track 1, left; track 2, centre; tract 3, control or auditorium; track 4, right. There was a variation on magnetic-optical (MAGOPT) prints which has an optical sound track measuring 0.97 mm in width located between track 2 and the picture. (b) Relationship between the tracks and the theatre: track 1, to left of screen; track 2, centre left; track 3, centre; track 4, centre right; track 5, to right of screen; track 6, control signals or environment.

6

Editing, cutting and post-production

Since the beginning of motion pictures, the continuity, that is the time scale and sequence of the scenes, with which the pictures were projected, was not the same as the continuity with which they had been filmed. Film scenes were, and are, shot out of sequence, pieces are omitted and the assembly of the scenes is in the control of the film maker. This is called **editing**, and the process of rearranging the sequences to fit the film maker's needs is called conforming.

This initial tampering with the continuity of filmed pictures was possibly the result of the need to remove damaged frames, but editing was also carried out on the story. Little by little, yet quite rapidly, editing took on a fundamental importance to both constructing the story on film and to preparing the original materials for printing.

6.1 EDITING STAGES

The process of editing a movie is carried out in two consecutive stages. During the first of these two stages, the process called editing is done on a print of the filmed material, when the materials are selected and the motion picture story is constructed. For sound films, this stage is done on two film strips, edited at the same time in conjunction with one another, the picture and sound.

In the second stage, called negative cutting, negative matching or montage, is where negatives are cut and joined to prepare them for printing. Negative cutting has probably only been done since about 1930. Before that the negatives were printed and the prints were joined (called positive cutting or positive assembly) to make the final print. Thus in silent films, the process of cutting and joining the negative for printing did not include the final constructing of the story which would later be done on the release prints.

The sound negative was made at this stage until the development of magnetic tape when the final mixed tape was made in synchronism with the picture and a single complete optical negative made from the final mixed tape.

6.1.1 Film cutting and splicing

Changing the film means cutting the film and rejoining it, often called splicing. A splice is a join in film made by overlapping the film and cementing, or gluing the sections together. The solvent acetone (2-propanone, CH_3COCH_3) became a crucial factor in the development of film making technology. It dissolves the film bases and enables them to fuse. Until the 1960s, solvent-made splices were the only possible way of piecing together the segments of filmed material. To have enough overlap for making these splices, the two frames to be partially overlapped must be properly cut. One of the frames is cut through the imaginary line connecting two sprocket holes, the other one must be cut to the edge of the next sprocket hole in line. This technique makes it necessary that one frame be lost at each splice.

For many years, this splicing was done manually. Splicers, mechanical devices to assist, speed up and improve the security of the process of splicing, were progressively used to a greater extent and served to ensure the aligning of the film and control frame cutting precision.

In the 1960s, pressure-sensitive self-adhesive tape first started being used for splices, which did not stay in good condition very long, required overlapping frames and afforded the possibility of readily making and taking apart the splices. These were ideal for editing. When polyester film base (which is highly resistant to the usual solvents) was first used, a new method of splicing film was developed, using a controlled heat or ultra-sound source to heat and seal the sections together, a form of welding.

6.1.2 Filming

The original camera negative (the 'OCN'), the material exactly as it was taken out of the camera, will include good or bad takes of each shot and may contain segments (such as camera start-ups, identifying slates, which tell the film maker which shot the film is, and so on), which will never be used in the final film and need to be removed. When talking motion pictures were first filmed, the clapper was added to the slate in order to simplify synchronization of picture and sound. Until magnetic tapes were developed, the sound recording was done on negative film.

On the edge of the negative is an edge number (the footage number) which is exposed as a latent image by the film stock manufacturer. This can be copied onto the prints to identifying each frame with its negative to assist with cutting later.

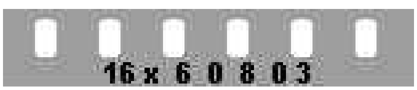


Figure 6.1 Edge numbers on original camera negative film

6.1.3 Developing negatives and printing

After developing, the original camera negative was, and sometimes still is, printed to assess the quality achieved. This print, called a **rush print** in the UK and a **daily** in the USA, will later be used as the workprint.

Computer editing systems and bar codes are used to keep a record of negatives and some modern film stocks use keycoding, a bar code referring to each frame. Today most negatives are transferred to videotape and edited as tape.

When sound was recorded directly onto the film, the materials of the original sound negatives shot were processed the same way as the picture. Sound negative filmed during shooting was developed and printed as a sound rush print to be used in the editing process.

6.1.4 Preparing materials for editing

When sound recordings were made on unperforated stock these were transferred to perforated magnetic stock of the same pitch as that used for the picture. In the editing room, the magnetic sound and the image rush print (now the **workprint)** are cut. Each picture or sound **take**, or scene, is a small sized roll marked with the numbering on the slate/clapper and with the first and last picture negative footage number.

6.1.5 Editing a sound film before video

The editing process is a process that is carried out on the work print and sound rush print until the director or editor is satisfied with the result. Editing tables have small projection screens to view the scenes in order.

Using the selected picture takes, the workprint, the exact position of the effects (fade-ins, fade-outs and dissolves) and how and what length they need to be are also marked and incorporated onto the negative as written instructions, using codes and symbols that have become standardized by time alone.

The sound takes, which are processed in the same way as the picture takes, or in the form of perforated magnetic tape, are selected. Each track is usually separate sound material (e.g. dialogue, music and effects) in rolls of the same length as those of the workprint, with which they are perfectly synchronized. There may be several different sound element rolls, which will eventually be compiled into a single track.

Any new sound which must be recorded later (effects) or which must be repeated (dubbing speech etc.) are logged.

The need of synchronizing with sound led to the widespread use of machines (editing tables, viewers) that screen the image at the actual speed synchronized with the sound tracks.

The conformed, matched or cut (all terms meaning joined up in the final sequence) negative may not include the titles and credits (or may incorporate markings to indicate where they are to go). Certain effects such as fade-ins, fade-outs, dissolves and wipes were made in the camera during the shooting in the 1920s. Later these were made as special printed effects from conventionally shot negative in the laboratory and then joined into the cut negative.

6.1.6 Editing silent film

The techniques employed in the silent screen era differed appreciably. In order to select the frames to be used, many film editors held them directly up to the light to look at them without seeing them in motion, and many worked with the original negatives. The film negative was often not joined to make one complete roll but the scenes requiring the same tint or tone assembled together for printing. The film was finally assembled as a print.

The idea of a roll or reel, the common unit of measure in the motion picture industry, is not, and never was, directly related to a length of the film. It originated partly due to the length of print film stock the manufacturer provided and partly due to the convenience of loading a projector. The greatest wear and tear on a roll is at the beginnings and ends so a long roll retained quality. Longer rolls are simply more risky to handle and may be dropped or loosened. Today there is no standard, but 80 years of custom dictated the 'roll' as measuring around 300 m or 1000 ft of film in length.

6.1.7 Sound mixing

During the recording process, each one of the sound elements on the synchronized tracks is adjusted to the degree of loudness most suitable for listening purposes. After conforming, all of the synchronized tracks are mixed onto one single element, the mix track. When this new track is being recorded the loudness and tone of each sound element is modified to suit the needs of the movie as a whole.

The preparation of versions in other languages usually involves making another mix track. Sometimes a single track minus the speech is mixed, called the international track (i.e. just the music and effects). This is mixed with a new dialogue track recorded in the new language.

6.1.8 Negative cutting, matching or conforming

After the laboratory effects which were marked during the editing process have been filmed, following the instructions included on the workprint, the original negative is cut precisely to length – to match the workprint frame by frame – and spliced together.

6.1.9 A&B cutting

The small size of 16 mm negatives results in a splice that is visible on the screen. A&B cutting is a technique used to avoid this. Two rolls of negative are assembled. Each roll has alternately a negative length and a piece of black film called spacing. The negative alternates between the two rolls. The overlapping splices are hidden on the black spacing at each join. The rolls are called the A roll and the B roll. Fades and dissolves can be made this way too.

To make a print, the positive stock is run through the machine twice, once with each negative roll. Today 35 mm film is usually cut in A and B rolls in order to incorporate fades and dissolves which used to be made as separate special effect sections and cut into the negative roll.

6.1.10 Conforming negatives of colour separation systems

Conforming in systems for colour which, like Technicolor or Cinefotocolor, used to be filmed directly onto two or three negative films, was identical to the system discussed above, but, of course, had to be done for all three separation negatives.

6.2 SILENT FILM NEGATIVES

The editing of the workprint (sometimes called 'positive cutting' or 'positive assembly') seems to have been universal since the very start of the cinema. The negatives were not usually

Figure 6.2 Title and credits of a silent film

conformed by being joined in a single length. Usually it seems they were assembled in groups or lengths depending on the grading and contrast and colour needed in the print so that they could be treated uniformly for each roll.

Apart from this, the capacity and flexibility of printers, developing and drying equipment drastically limited the length of the rolls in which the negative could be printed. For example, up until 1927, most of the film making laboratories in Spain could not take rolls over 60 metres (200 ft) in length.

The complexity of tinting and toning added to the difficulties of creating a single run cut negative.

6.2.1 Adding credits

The titles and the credits used to be filmed separately (often directly in print form by photographing boards drawn to look like negatives). In order to indicate where the title was to go in the final film one of the title frames was filmed with a number or some text. Sometimes this was just a recognizable mark.

6.2.2 Conforming negatives and constructing prints

All of these limitations and needs seems to have created a complex system in which negatives were put in an order based on several simultaneous, overlapping criteria. This type of work was never standardized, as there were probably as many different approaches as there were editors and laboratories. The terms sections, blocks, part and roll were occasionally seen on negatives and leaders and probably refer to a local concept for juggling grading and colours in order to print the minimum number of printing lengths for each final print. Complex numbering systems obviously existed too.

Once printed and processed and/or coloured, the sections of prints were broken down into scenes and reassembled into the final theatrical print. Each print length was made over-length to allow for a frame at each end to be lost on splicing. This needed a great deal of labour in some large laboratories.

6.3 SOUND NEGATIVES

A sound negative is the film length that contains all of the sound mixed and transferred to film in negative form and ready to be reproduced on the print. In the 1930s and into the 1940s, optical systems (with the exception of gramophone records) were the only ones used. Sound had to be recorded, edited and reproduced entirely photographically.

Throughout the first few years, the negative which was in the sound cameras during shooting was conformed directly to the final negative. If different equipment was used for filming (if for example the equipment differed in density in the studio, and differed in area for shooting exteriors), the sound negative would also show these same variations. This did not greatly affect the sound

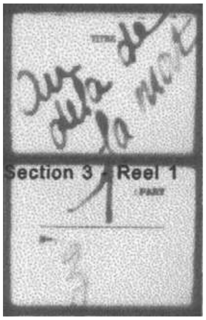


Figure 6.3 Details on a silent film leader to indicate the colours and the print cutting sequence

reproduction quality. These variations produced in the sound track camera can also be seen on the print.

6.3.1 Splicing

Splices made in picture stock are located between two picture frames. The transparency of the film interferes with the splicing of sound tracks, and every splice is an audible click. To silence this problem, a triangular-shaped perforation (a silencer or 'bloop') is made on each splice. This is reproduced as a dense triangle on the prints, the gently tapered sides of which will close and will re-open to allow the light beam through the track to rise and fall uniformly, thus giving rise to much less noise than would be caused by a straight-edged splice.

On magnetic stock, pressure-sensitive tape is used and is placed on the base of the film As this type of splice is made on one side alone it is not extremely strong, so the stock is clipped diagonally in order to spread the stress.

6.3.2 Post-production sound

The need to enrich and dramatize movie sounds by mixing tracks that were difficult to record simultaneously with the image, or simultaneously with each other led to the invention of post-production sound systems. The original recordings are first conformed separately and are then recorded on a new film base. Until the 1950s, this entire process was done on optical recordings, and the

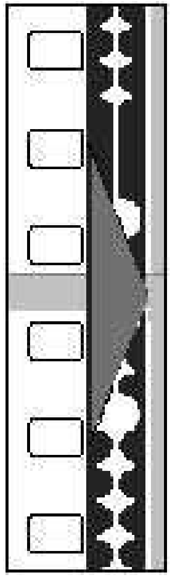


Figure 6.4 A silencer or 'bloop' at a splice of a sound film

sound workprints which had been conformed during editing were played out through optical heads in synchronism with each other, producing a mixed signal which was re-recorded as a single track on negative stock.

This system did away with sound negative splicing (except splices for correcting errors or resulting from censoring) and considerably increased the sound quality. Also, because the film was in one piece, it reduced the risks during printing. The use of magnetic systems and digital sound editing systems has introduced no major changes in the process of making sound negatives.

6.3.3 Synchronization in printing

The finished sound negative and the picture negative are now cut into rolls of the same length and incorporate the protective head and tail leaders. 'Start' marks – just crayoned crosses or some other recognizable mark – guide the operator of the printer to position the two films in precisely the right place in the picture and sound gates of the printing machine. These printing process adjustments may vary according to the machine in which the printing is done.

7

Colour

7.1 LIGHT AND COLOUR PERCEPTION

White light is comprised of all of the colours which the human eye is capable of seeing. The colours which an object appears to be depends on the light that illuminates it, and qualities of the object itself which allow it to reflect light. An object illuminated with white light will be seen as being **white** when it reflects all the wavelengths in the spectrum, in the same proportion and intensity. When an object absorbs some part of the light of all of the wavelengths, it will be seen as being **grey**. An object will be seen as **red** if it reflects solely or mainly the red wavelengths light. It will be seen as **black** when it absorbs all of the light and reflects none.

The colour of any object will also depend upon the colours of the light shining on the object. When the light shining on the objects is not white, it modifies the colour seen. For example, two surfaces which would be seen as being violet and blue, respectively, when illuminated by white light would, when illuminated with blue light, both be seen as being violet (although probably different shades) because they both reflect blue light.

7.2 SILENT SCREEN ERA COLOURED FILM

Motion pictures originated in monochrome (black and white), but inventors continually attempted to introduce 'natural' colour to make the images as realistic as possible. Several small-scale ventures produced a few impractical natural colour films from 1910 to 1935. However, for more than 30 years (1900–1930), the industry used alternative colouring methods to colour film; these were not natural and were not as a result of analysing the scene photographically, but used arbitrary colours. These systems were popular and met with such great success that nearly all silent films, although they were originally filmed in black and white, were viewed by moviegoers as coloured prints. When optical film sound came out, around 1930, requiring its own individual requirements for the conforming of negatives and the making of prints, these colouring methods quickly ceased. For a while – in some countries up to ten years or more – all cinema films were seen only in black and white.

7.2.1 Colouring systems

During the silent screen era, a number of processes were developed for colouring prints. Each of these systems developed technically over the period: some were often done completely by hand, and combinations of two systems were frequently used, achieving pictures that were certainly not true-to-life, yet were extremely beautiful. Sometimes both coloured and uncoloured (i.e. cheaper) versions of films were released.

Colour, due to its high cost, was generally used for productions short in length. In many cases, uncoloured prints, which were sold more cheaply, were made at the same time.

Hand-colouring

Hand-colouring was done directly using brush and water-based or alcohol-based artificial organic dyes to areas on each individual frame, on the emulsion side. No matter how skilled the person doing this hand-colouring might be, the coloured 'spot' in each area never coincided exactly with that of the following frame, and the areas of colour jumped around and constantly changed shape on the screen.

Stencilling

To keep these coloured areas as still as possible and to mechanize this system and reduce the cost, a stencil cut out in the shape of the area to be coloured was used as a guide. The stencil areas were coloured using a dye-soaked pad, placing the stencil on first one frame and then the next until the object that was being coloured changed shape and a new shaped stencil had to be cut.

This tedious process was almost completely mechanized in the Pathé colour process. The stencils were a film strip the same length as the film print. The apertures were cut for every frame using a blade mounted on a pantograph, and a remarkable degree of precision was achieved on tracing around the colour areas of an enlarged frame image. The dyes were applied with a roller applying dye through the stencil, which was transported on top of the print. Up to six colours on each frame were possible and many identical cinema prints could be made.

Tinting

Tinted films were dyes entirely, with the dye colouring the emulsion of developed prints. Originally the dyes were probably hand-brushed onto the surface using a pad or roller, as they were with lantern slides.

In later post-tinting systems, the print was immersed into water-based acid dyes and then dried. This method became widely used, and many laboratories installed tinting facilities. The tint systems were used on the entire frame. On screening, the high-density, black areas remained black and the clear areas were the colour alone – a scale from black to the tint colour.

In the 1920s, some film base was factory-dyed before coating the emulsion. This achieved degrees of uniformity which surpassed those achieved in many laboratories.

Some dyes could be applied mixed with an organic varnish and applied by brush. When sound was introduced, some manufacturers (e.g. Kodak, Sonochrome) continued to sell factory-dyed print material, although the dyes were carefully selected not to alter the sound quality. However, these were never successful as sound made positive assembly of the print impossible.

Toning processes

In these systems, the photographed silver print image was replaced by a dye by means of a chemical process. These processes were always done in a laboratory using a finished processed print.

In many toning processes, called **metallic toning**, the silver of the photographed picture will be replaced by other metallic salts (gold, copper, uranium etc.). These were often ferrocyanides or sulphides. The toning process dyes the image leaving the clear areas unaffected – a scale from colour to clear or white.

Mordant dye toning used organic 'basic' synthetic dyes available in a much wider range of colours. A 'bleach' solution first converted the silver image back to white silver salts and the dye was mordanted (chemically bonded) to the silver salt.

7.3 NATURAL COLOUR REPRODUCTION

There are always two stages to photographic reproduction of colour: **Analysis** – this has always an 'additive' procedure in photography and television, recording the relative amounts of red, green and blue light in an image – and **Synthesis** – recreating the original colours. Synthesis is usually **additive**, using red, green and blue light, or **subtractive**, using cyan, magenta or yellow filters, or some other combination, to selectively remove colours from a white light source.

7.3.1 Additive synthesis

When red, green and blue light is added together the human eye sees the combination as being white. These three colours are known as **primary additive colours**.

Any colour light can be obtained as different combinations of the three primary colours: **red + blue** makes **magenta; blue + green** makes **cyan** (greenish-blue); and **green + red** makes **yellow**.

Cyan, magenta and yellow are said to be **complementary** to primary red, green and blue, and adding a primary colour light, e.g. blue, to its complementary colour light yellow (made up of green + red light) will make white light (red + green + blue).

Additive synthesis takes place in the human eye. In the retina the three different cones sense the primary colours and the combined visual sensation is that of white.

In both still and motion picture photography, one process after another attempted to recreate colour using additive synthesis. Some of these processes involved projecting red, green and blue images on a screen one at a time and relied on the persistence of vision to make them appear to be projected at the same time. Some of these were of very high quality, but were impractical for general use in a cinema.

Other processes were based on arranging the emulsions or the filters in mosaics or grids in which each cell records one single colour image. These systems were always very complex and printing was particularly difficult. No mosaic additive system was really successful until colour television, in which the light signal for each primary colour is analysed separately and is directed to a phosphor that emits the same colour light on the inside of a cathode ray tube.

7.3.2 Creating colour by subtractive synthesis

Additive synthesis uses red, green and blue light. Coloured filters can be overlaid to produce other colours but these primaries are cyan, magenta and yellow, called the **subtractive primaries**. (Overlaying red, green and blue filters will not produce a range of synthesized colours – if a red filter allowing only red to be transmitted is used in combination with the effect of a green filter which absorbs red light, the appearance will be black.)

Each subtractive primary colour filter transmits two-thirds of the spectrum and absorbs one-third**.** For example, a cyan filter transmits the wavelengths of green and blue. A yellow filter transmits the wavelengths of green and red. If a yellow filter is laid on a cyan filter, the yellow will filter out the blue light, but will allow green light to shine through, and the cyan will filter out red light, and allow green. Therefore the only light transmitted will be green. Cyan, magenta and yellow in varying strengths of filters can be used to recreate any colour.

The three additive primary colour lights = white.
The three subtractive primary colour filters = black.

The use of subtractive colours to recreate colours is called **subtractive synthesis**. White light from the light source absorbs (i.e. subtracts) light to achieve the colours.

7.4 NATURAL COLOUR MOTION PICTURES

7.4.1 Additive systems

Additive colour systems were numerous but rarely successful. Two different technologies were commonly tried: using multiple images and combining these on the cinema screen and using a single image broken up into separate mosaics of colour.

Typically **multiple images** were made on black and white stock, using a filter to select the range of colour analysed. The first negatives were called **separation negatives**. Sometimes the images were in sequence on the print, sometimes they were separate film strips and sometimes images were arranged across the film width. Projection varied widely. In sequential frame systems, the film was run through at double speed, and the colour was selected using a rotary shutter equipped with a suitable filter for each frame. In the 'Francita' system, three much smaller-sized frames shared the height of five sprocket holes. They were filmed using a prism (a beam splitter) which created three separation negatives by exposure through three filters. The same beam splitter system in reverse recombined the images in projection.

7.4.2 Mosaic colour systems

In the Dufay system, the most famous and the only system which met with industry-wide success, the mosaic, or réseau, was comprised of 25 micron red filter strips separated by 25 micron square blocks of green and blue between the red. The réseau was mounted on the film base and was coated with a black and white emulsion on top. The exposure was carried out through the base, and tiny separation negatives (or positives by a reversal process) were formed behind each filter element after processing.

7.5 SUBTRACTIVE SYSTEMS USING BLACK AND WHITE NEGATIVES

The first industrial subtractive systems were based on the same red, green and blue separation negatives first used for additive systems but used subtractive synthesis (cyan, magenta and yellow dyes) rather than additive synthesis (red, green and blue light). The film camera images were formed by a single lens, but either the beam was split into three to expose the three films or two of the films were transported through the camera gate together, called a **bipack**. In some systems only two separations were made, in others a bipack produced two separations and beam splitting achieved the third. The prints were made by numerous methods.

The **Technicolor** system, the most famous of all these systems, was a series of different processes at different times, all more or less based on these principles. From 1935 to about 1950 large and complex cameras with both beam splitters and bipacks were used. The three separation negatives that resulted were used to produce three **matrices**, positive prints in which the emulsion with the images was hardened and the remainder washed off with hot water to leave a relief image. Each of these matrices was dyed cyan, magenta or yellow and the dye transferred in register one after the other onto a blank gelatine-coated film. The red separation resulted in the cyan matrix, the green separation in the magenta matrix, and the blue resulted in the yellow.

The numerous **two-colour** systems like **Cinecolor** (USA and UK) used only two separations and two subtractive primaries. Many of these systems used regularly available bipack film stocks made by most large film manufacturers. Some systems were extremely local and were given local names, e.g. **Cinefotocolor** in Spain and **Dascolor** in Belgium.

The two bipack negatives were used in this system, one of which was a red–orange separation and the other a cyan–blue separation. There were numerous different printing methods, but they generally used a cyan–blue dye for the red–orange separation and vice versa. In some systems the film had an emulsion on both sides of the base. One separation was used to print one side, and the other separation, the other. Different processing methods were used to produce images toned the right colour. Many of these processes produced excellent results although by no means perfect and all the colours produced are only approximations to their original hue. Many were tinted yellow overall in order to make the greys more neutral and give a more realistic effect!

7.6 SUBTRACTIVE COLOUR NEGATIVE SYSTEMS

Integral subtractive synthesis colour film systems were first developed in the 1930s, initially by Kodachrome and Agfacolor alone, but today these systems are the only ones used. In these systems the three layers sensitive to red, green and blue that separate, i.e. analyse, the subject are coated on one film base as a sandwich. The processing produces the dyes in the correct layers. By choosing the process method, either a negative–positive system or a direct positive (a reversal) system can be created. The motion picture industry uses the negative–positive system today but reversal systems were also used, especially for news film.

7.6.1 A typical tripack colour film

A typical colour negative film has four significant layers and several less important ones. The top layer is blue-sensitive, the next is a yellow filter layer, then a blue-and-green sensitive layer, finally a red-and-blue-sensitive layer. The image is focused on the emulsion. The blue separation is formed in the top layer. The yellow filter layer absorbs all blue light so that no blue is transmitted to the middle and lower layer, so green and red separations are created in these layers. Processing develops silver in these layers as a negative, but also in the layers are **couplers.** A coupler is an organic chemical that combines with oxidized developing agent to form a dye. The couplers are selected to form yellow, magenta and cyan dyes in that order. The result is a negative – negative in density and colour. Silver is also present and this is bleached out chemically leaving solely the three dye images superimposed.

Printing a colour negative onto a similar tripack film produces a colour print.

Many films do not quite follow this pattern. Layer orders do vary, especially for print films and some films are processed as a reversal to make a positive. Some films are not coated with the couplers in the three emulsions, and the couplers are present in special developer solutions instead (e.g. Kodachromes).

7.6.2 The stages in the processing of a colour negative

- **Step 1 Exposure:**
  The top layer is blue-sensitive with yellow-producing colour couplers.
  The middle layer is green-sensitive with magenta-producing colour couplers.
  The bottom layer is red-sensitive with cyan-producing colour couplers.
  A white object will expose all three layers.
  A black object will not expose any layer.
  Coloured objects expose the layers sensitive to the wavelengths of their colour sensitivity.
- **Step 2 On development** both dyes and silver are produced.
- **Step 3 After bleaching** the silver image and the yellow filter layer are removed.
- **Step 4 After fixing** the silver salts are removed and the film dries to a transparent negative image.

Both colours and brightness are as a negative.

7.6.3 Printing

The printing process is identical to the negative process, which, just as for black and white photography, could be done using the same emulsion (although special films are made for each purpose).

7.6.4 Integral masking

In the first colour negatives all the colours were seen in negative and so was image brightness. Deep shadows were clear film and highlights black. From about 1950 in the case of Eastman colour negative and later for some other film manufacturers, negative films appear to have a red–orange overall colour. This is called integral masking which significantly improves the colour fidelity of the final print.

8

Motion picture film materials

8.1 THE RELATIONSHIPS BETWEEN FILM MATERIALS

The earliest film materials were made to provide two requirements, a camera negative material and a print film. It seems likely that initially these were very similar, and as the industry became more demanding and the need for many prints increased camera negative films and print films separated in character. Negatives must be fast and sensitive – print films should not be very sensitive otherwise safelights cannot be used. Perhaps as early as 1900, certainly by 1910, negatives adopted a general contrast of about 0.4 to 0.7 and print films a contrast of about 2.0 to 2.5. It was not until the 1920s and the science of sensitometry developed, largely by Eastman Kodak under the direction of Dr Mees, the head of research, that definition and calculation of speed and contrast became in any way standardized. Today all camera negative films, both black and white and colour, have a contrast of approximately 0.6, and print films a contrast of approximately 2.5.

Duplicating materials to make duplicate negatives are not so standardized. Black and white duplicating films use contrasts for master positive film and duplicating negative film, which are not the same. This results from the practice first developed in the 1920s and 1930s by Kodak and Pathé. In order that the duplicate negative is as close a match to the original negative as possible, the two contrasts multiplied must equal 1.0 (see reference to the Contrast Rule later).

When Kodak introduced colour duplication in the early 1950s they took the opportunity to create a single duplicating film for both master positive and duplicate negative. Both had and still have a contrast of 1.0.

Most film manufacturers have produced schematic diagrams to show the relationships between their products. The Eastman Kodak 'Network of Materials' sheets of the 1970s are some of the most graphic.

The following diagrams show the relationship between different film material types for a number of generalized black and white and colour systems. Figure 8.1 shows the film materials available today and their purpose.

The modern colour system (Figure 8.2) is based on currently available Eastman Colour films.

Any film material is capable of producing one or more different **elements**. For example Eastman Colour Intermediate Film (there have been about four different steadily improving versions all with the same name but different code numbers) was designed to be used to make both a master positive and a duplicate negative.

Another film stock, Eastman Colour Print Film (over 17 different versions and numbers since 1950) is only ever used to produce a colour print. However, several methods can be used to achieve this print – conventional printing from a colour negative, register printing from two or three separation negatives, or by the Desmet method (see later).

Eastman Panchromatic Separation Film was, and still is, made in order to make separation positives (often called Protection Masters) from colour negatives for archival storage. However, such a useful film stock has a wide range of uses for archival film restoration and can be used for making negatives, separation negatives and even masks (see later). Thus some film materials are used to make a range of different elements.

In addition to negative–positive colour systems, reversal processed tripacks yield

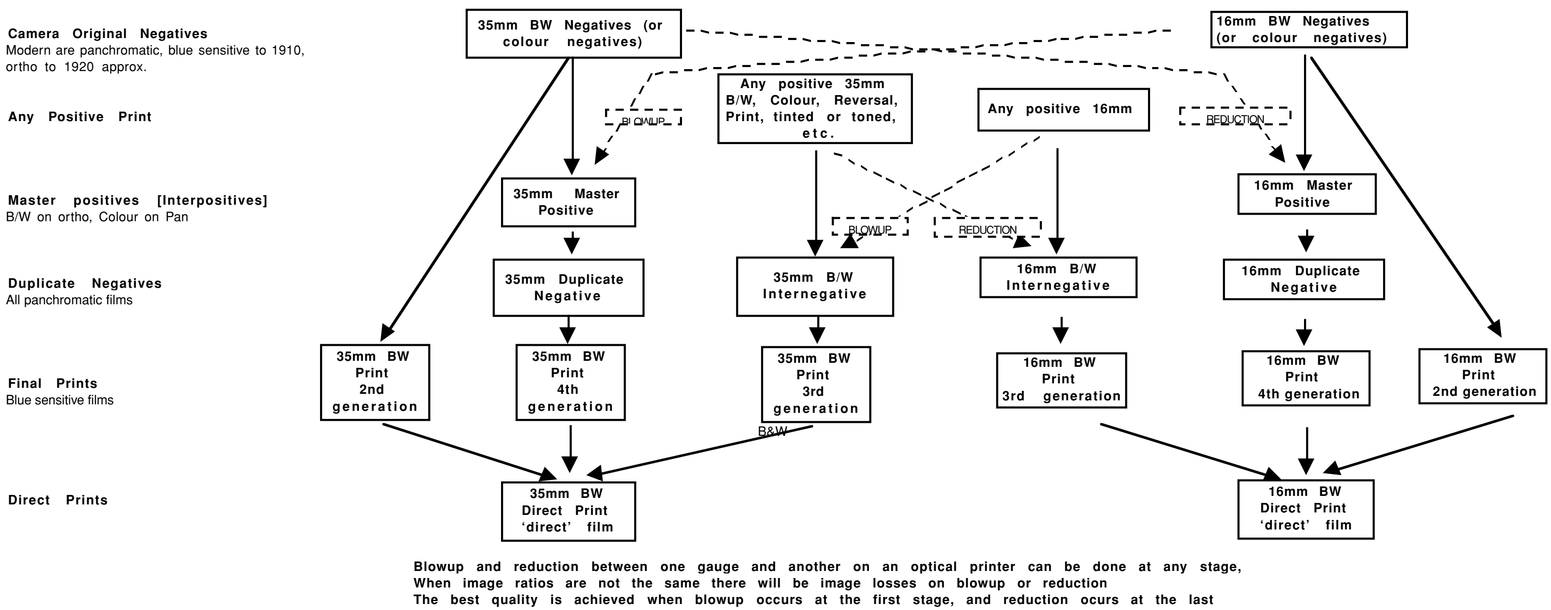


Figure 8.1 Black and white duplication routes

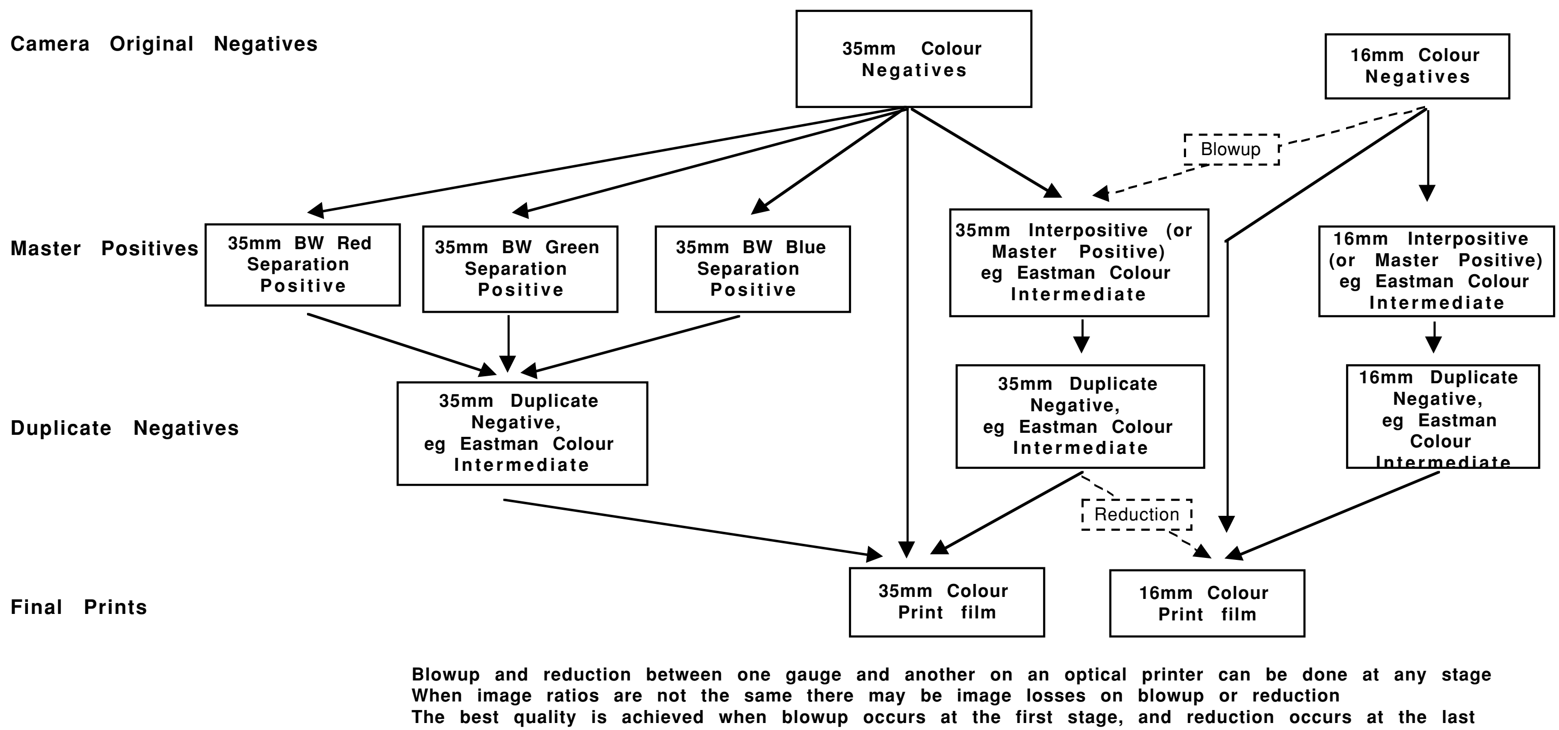


Figure 8.2 Modern tripack colour negative/positive printing systems

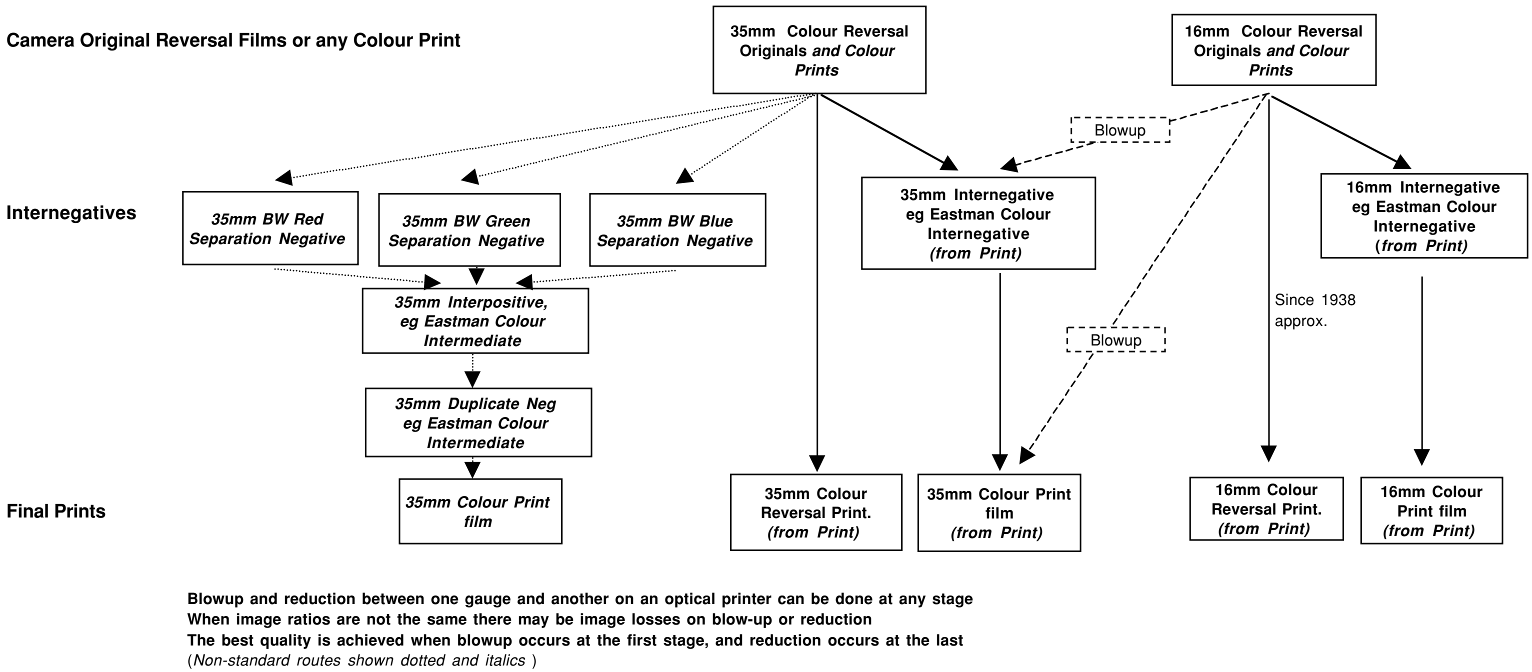


Figure 8.3 Colour reversal routes and printing from colour prints since about 1955

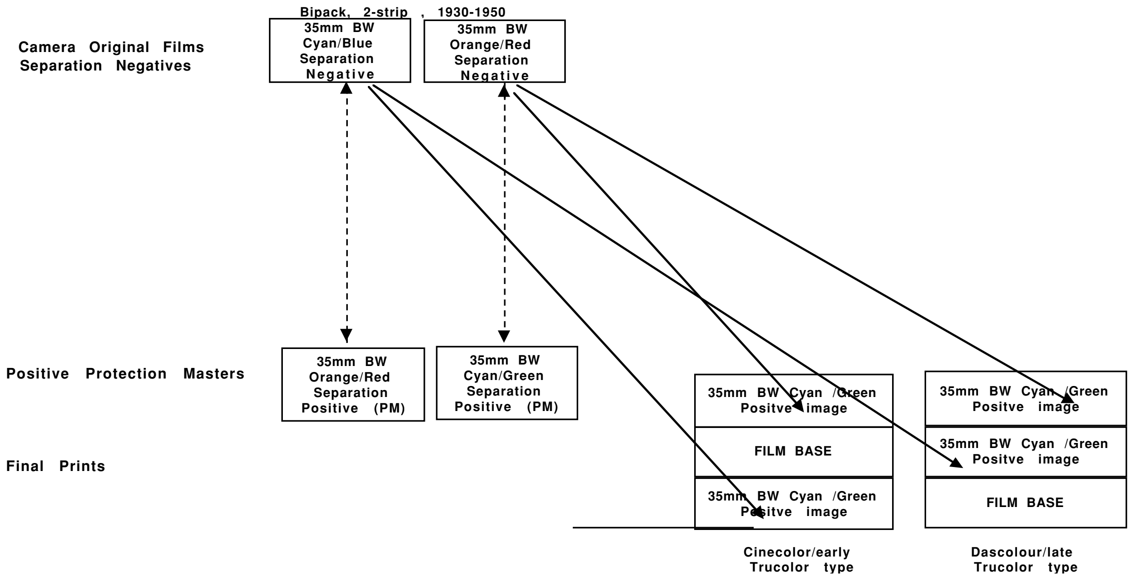


Figure 8.4 Two-colour or beam splitter, 2-strip systems (Cinecolor, Trucolor, Dascolour, Cinefotocolor etc.)

direct positive images. These have been very important in amateur, newsfilm and for industrial and scientific films.

The two-colour and Technicolor diagrams (Figures 8.4 and 8.5) give some idea of some of the previous and most commercially used colour systems prior to Eastman Colour and other integral tripack films.

The terminology for these different elements has always been a major problem, particularly in English. Manufacturers have their own set of terms, so do countries, technical societies, standards organizations and even laboratories and television companies! The Glossary attempts to make some sense of these.

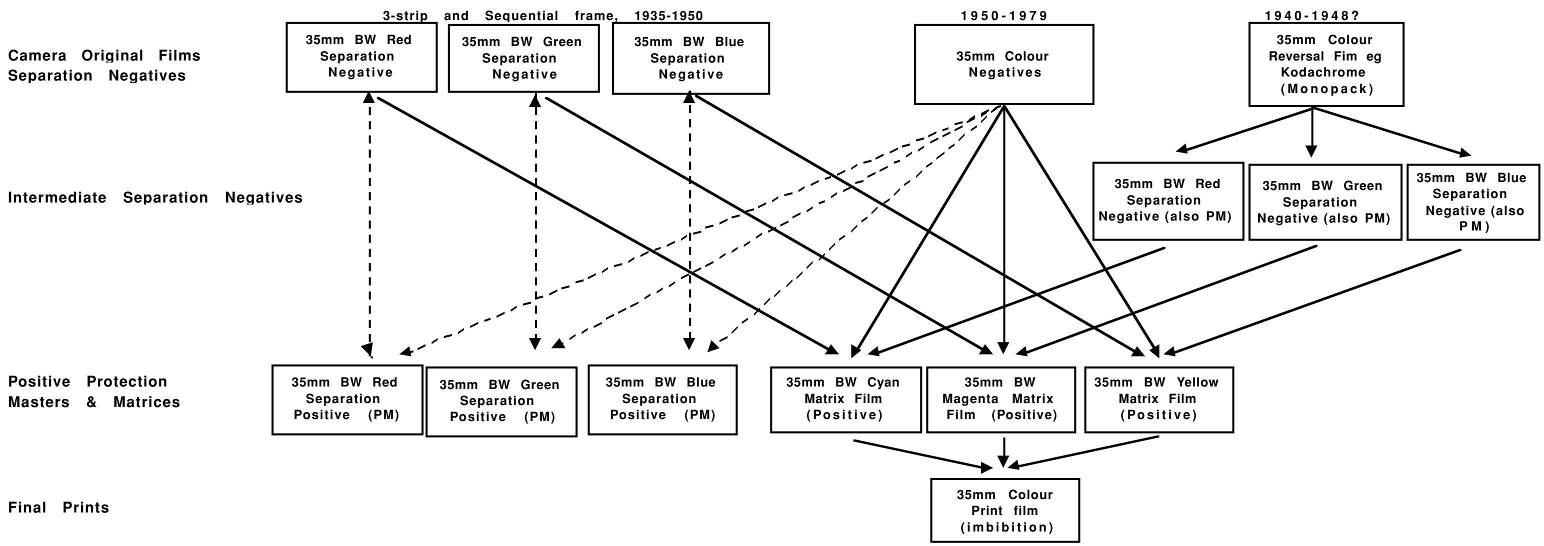


Figure 8.5 Technicolor 3-strip (1935–50 approx.) and Technicolor Print (1940–75 approx., 1991 in China) systems

Part 2

RECONSTRUCTING A FILM

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9

Identification of archive film and interpretation of historical data

9.1 INTRODUCTION

The identification of a reel of film is for two purposes:

- To identify the film title, actors and/or events, period, and the context in which the film was made. The evidence will be principally from the images, and from additional written matter on the film itself.
- To provide the restoring technician with information to produce an authentic restoration. This evidence will be from the images also, but in addition, from the film itself, from the gauge, sprocket holes, edgemarks, dyes, soundtracks and many other characters.

The two aspects above are related and date is usually critical. If the film is not dated the period may be estimated from the photographic material, the element. Identifying a colour process can sometimes date a film within a few years. Alternatively, recognizing an actor, or a theatre billboard in the image, may provide a date and help the technician decide how the film was made, and therefore how to restore it. The most difficult and ever-present problem that a film archive has to face every day is that of identifying materials that are either completely without opening credits or have them only incompletely.

At the end of the 1980s the Dutch National Archive took possession of an immense collection of about 2,000 titles that had been collected by a distributor in the early 1920s. They were mostly films without opening credits, or, at best, with credits translated into Dutch. The archive decided to tackle the work of identifying the huge collection over a period of several years and now almost the entire stock has been identified.

From that collection several masterpieces from cinema history, that had been forgotten or thought to have been lost, have come to light. The effort of the Nederlands Filmmuseum is a good demonstration of how working on collections of unidentified film means giving value to material that otherwise risks being forgotten. For example, let us imagine that an American archive has a French film stored away, important because it is believed lost, but its original title cannot be identified: that film is doomed, sooner or later, to decay and to die without anyone being able to intervene.

Identification demands a lot of experience. All the operations that are now being presented schematically eventually will become a daily working method. Eventually repetition provides the knowledge necessary to allow a worker to simplify and modify routines.

Identifying a film proceeds by a process of elimination.

9.2 THE NEW ACQUISITION

9.2.1 Before opening the can

Before anything else, you must try to ascertain where the film comes from. Look at the can label. If, for example, it has been deposited by a distributor that was active up until the 1930s, it is almost certain to be a film produced in that period. A careful study of the source of the material simplifies the work of identifying it. Check the number of reels of that particular film and, of course, start with the first one, if possible. Sometimes the can label has no relationship to the film inside.

9.2.2 Opening the can

Normally it is the practice of film archives to substitute rusty old cans with new ones, either in plastic or metal, in order to better conserve the treasure. While this important step is being carried out, it is necessary to meticulously register any and all information that might otherwise be lost forever.

9.2.3 Taking the film out the can

First look at the edges of the film. From this first observation you can see if the film is black and white, colour or coloured (the different tintings show clearly on the border of a coloured film) and therefore already start to calculate an approximate date as to the decade. You will know that an Eastman Colour film can only have been produced after 1950 and that a tinted film base will have been produced before 1930. Of course, in order to analyse the technical information contained in a film you will have to begin to unwind the reel and observe the film frame by frame through some form of simple projector. This initial dating of the film as to its decade will help you to better select the information that you have to look for.

Observing the edges of the film, you will see immediately if the film can be unwound, or if it might be damaged in doing so. If it is a nitrate based film and it is already in an advanced state of decay, swellings on the edges of the film, can be seen, or whitish or powdery discoloration.

Looking at the edge of the reel, you may also see immediately whether the perforations are damaged or not. In the event that there is much damage, you may also find small holes along the edges corresponding to the tracks of the lost perforations. Every piece of evidence should be recorded

Now the film can be unwound, very slowly.

9.2.4 Unwinding film

Sound films almost always have leaders. When they are the original negatives, they can carry the title of the film, the reel number, the name of the producer or the distributor and the name of the laboratory. For example, films, even prints, from the ex-communist countries usually had leaders that permitted the immediate identification of the country where it was produced. On the leaders, the laboratories in the United States, France, the United Kingdom and Germany usually put instructions for the projectionist in the different national languages.

On sound film leaders there could be instructions for synchronizing the film with the records that accompanied it.

If it is a silent film, it usually will not have any original leaders, but ones that have been added later. It is possible that on these leaders a title has been written by hand that corresponds to that of the film.

9.3 THE IMAGE AS EVIDENCE

9.3.1 First impressions

Often after the leaders there may be several metres of a film that has nothing to do with the rest of the roll. It was quite usual for collectors or newsreel companies to use pieces of spare positive film as leaders, spliced onto the real film. In England this was called **gash** film, and the practice was particularly common with newsfilm.

If it is a silent film where sound has been added later (sometimes called post-synchronized) image area will have been reduced by the soundtrack that has eliminated the corners and part of the frame. Normally, to add sound to a silent film a very simple soundtrack was used that contained music, sounds and rarely dialogue. However, many studios continued using cameras with the silent film frame order until the early 1930s, so that these films have 1:1.33 frames interrupted by the soundtrack even though they have been shot in the sound era.

If the reel is from the head and it is the first reel, after the leaders you might find the credits; the film, the director, the studio etc. It may be that only some of the original opening credits remain and that the title of the film itself is missing. Even then, sometimes only the name of an actor can be enough useful information to make a comparison with that in the filmographies. There are sufficiently complete filmography files for all the major national studios (at least for feature films) to permit the identification of a film's title even with only a few pieces of information.

9.3.2 Silent movies – intertitles

Very often the name of either the producer or the distributor is carried in the text of the intertitle. Knowing the name of the producer of the film is extremely important because this reveals its origin; information about the many distributors is less well recorded.

The intertitles normally contain either one or two series of numbers. If there is only one then it refers to the sequence of the intertitles. If the first one carries the number 30 then it is obvious that you are not looking at the first reel. This type of information is very useful in understanding the completeness of the material under study.

If there are two clearly separate numbers then probably one changes while the other remains the same. The unchanging number is the production number, while the other is the intertitle sequence number mentioned above. The production number may be on the intertitle, and there may be the company name as well. Alternatively the number refers to the distribution, but with the name of the distributor written at the side. The production number is useful in identifying a film, if the production company's catalogue is available.

9.3.3 Writing

There is usually at least one legible piece of writing as image in a reel of film: the name on a store window, the title of a newspaper, the name of a street, the advertising on a streetcar, etc. These are original to the shoot. The language in which they are written may tell us the country of origin.

9.3.4 Actors

A decisive element in identifying an untitled film is the recognition of the actors. If you can recognize an actor you have a good chance of finding the original title of the film. The actor may define the country and the period, and the filmographies should provide the rest.

By observing the hairstyles, clothing, automobiles etc., it is possible to acquire circumstantial evidence.

9.3.5 International collaboration

In general, someone, somewhere, will recognize an actor or provide the data that provides the lead. In 1993, the Cineteca of Bologna became the European Centre for the Search for Lost Films Project, proposed by LUMIERE in order to compile a list of films that the EU film archives consider lost, and help archives to identifying their patrimony.

9.4 THE FILM AS EVIDENCE

The film itself may be of great importance to the archivist – it may date the production or just date the print. Evidence will come from a wide range of different fragments of information:

- The film base
- The gauge
- Perforations
- Image size and ratio
- Edge data
- Number and frequency of joins
- The colour system/black and white process/tinted/toned/stencil etc.
- The element, negative/positive/duplicate/reversal/separation/colour/sound etc.

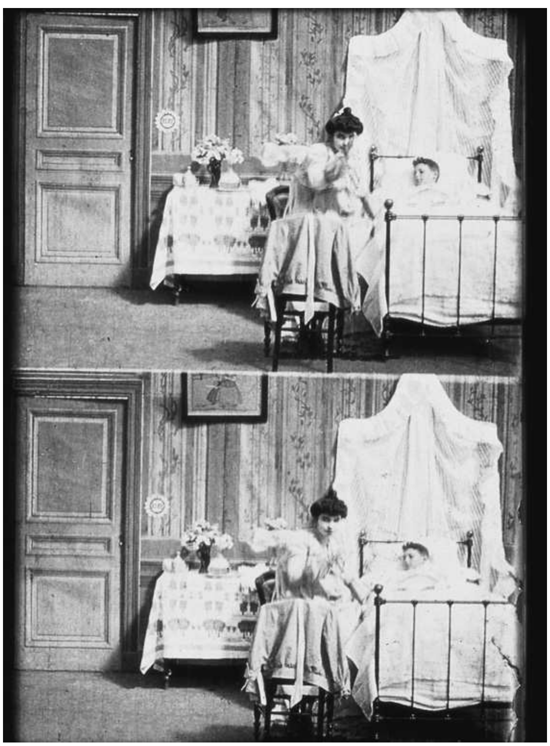
Since the very beginnings of motion picture film, it is believed there have been over 100 commercial colour systems, over 40 sound systems, at least 2,000 film laboratories worldwide, an unknown number of different film manufacturers and stocks and 100 years of innovations. A full list of all the pieces of evidence that could be useful is not possible and, indeed, does not exist. By definition, it also implies that certain identification is often not possible. In turn that means that truly authentic restorations are also not always possible. The FIAF/Gamma Group Madrid Project is a programme, started in 1999, to gather this information.


DER GERICHTSARZT
WEISS VON
DER TRUNKSUCHT DES VATERS
NICHTS UND HÄLT ROBERT
FÜR SEINE UNTAT FÜR
VERANTWORTLICH.
23.
"ÉCLAIR"

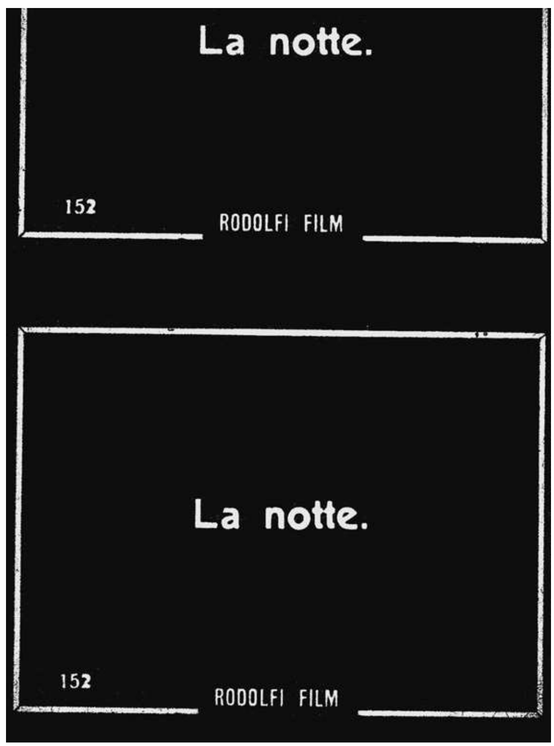
(*a*)


MOSES LEIDET UNTER
ALLEN, DEN HEBRÄERN,
SEINEN BRÜDERN,
AUFERLEGTEN UEBELN.

(*b*)



(*c*)

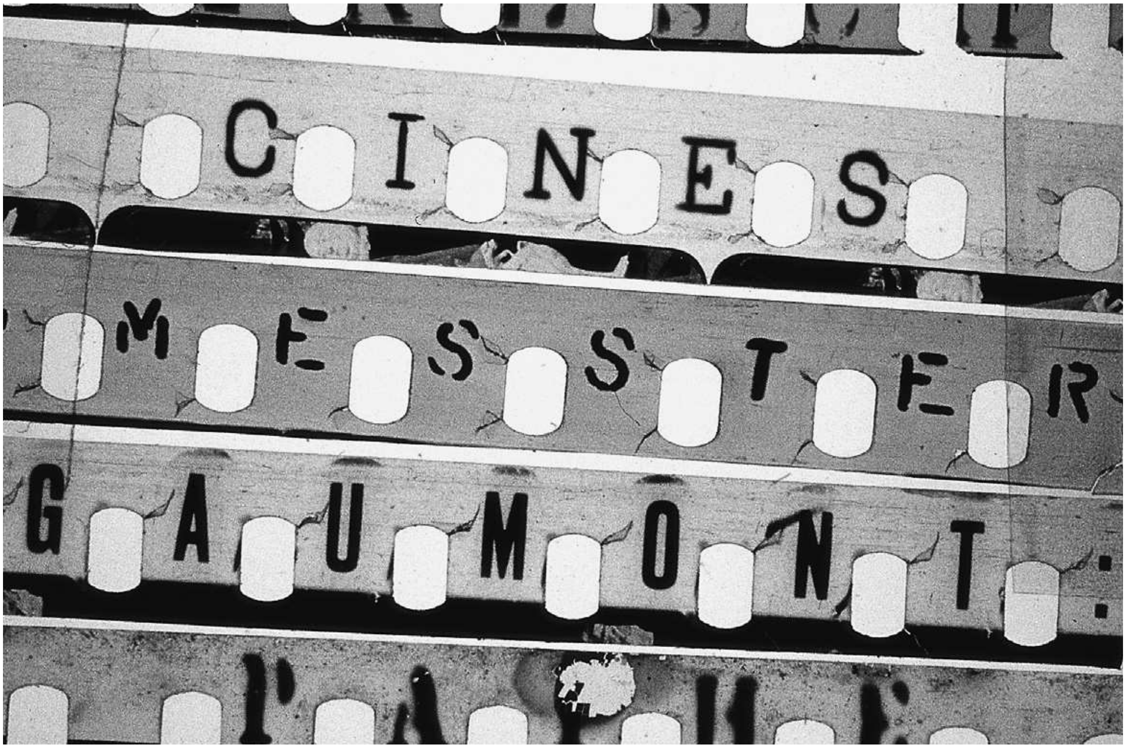

La notte.
152
RODOLFI FILM
La notte.
152
RODOLFI FILM

(*d*)

(*e*)

(*f*)

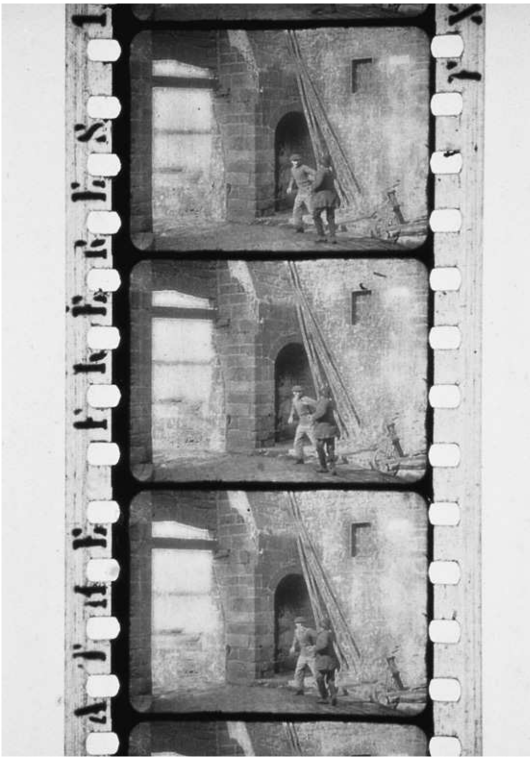
Figure 9.1 (*a*) Éclair intertitle; (*b*) Vitagraph intertitle; (*c*) clues to date in image; (*d*) intertitle with production company mark and intertitle number; (*e*) clue to date in image; (*f*) intertitle and company marks


CINES
MESSTER
GAUMONT:

(*a*)


·VITAGRAPH·
Ed infatuandosi sempre
più, egli le racconta
fantastiche storie di
briganti.........

(*b*)



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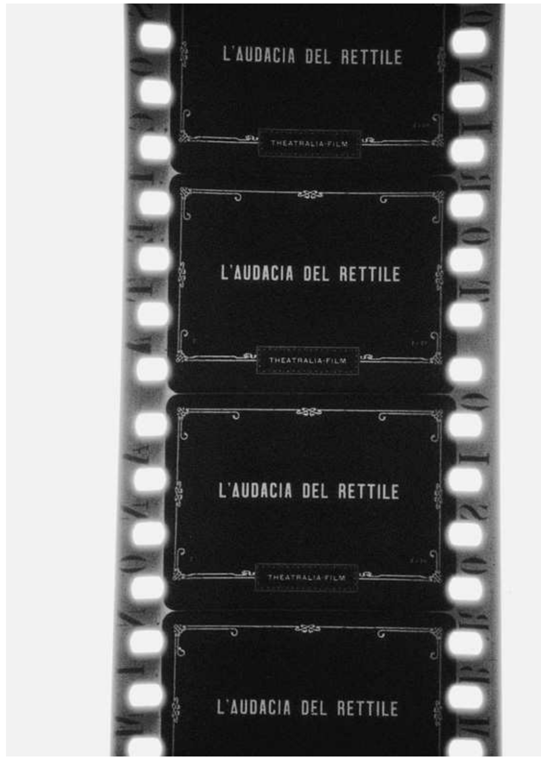
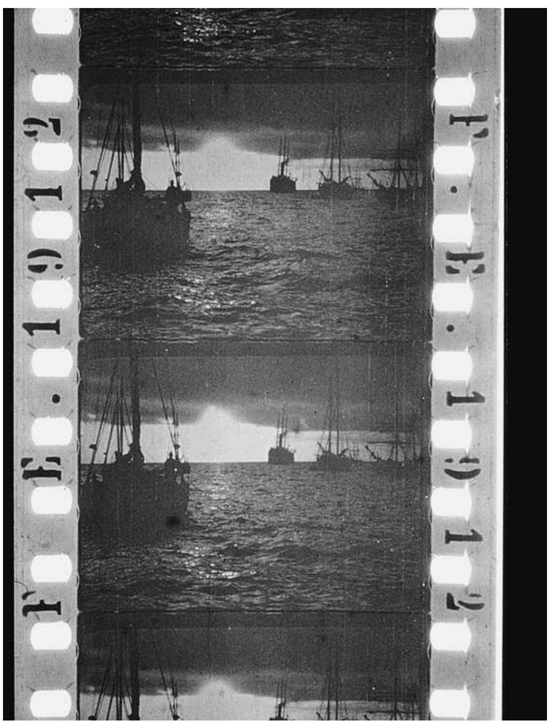
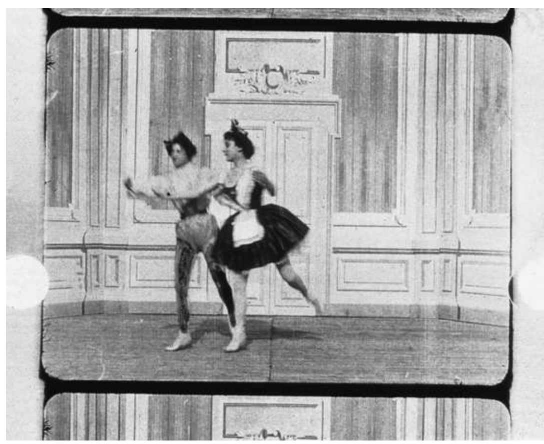


(*d*)



(*e*)



(*f*)

Figure 9.2 (*a*) A range of manufacturers edge marks: notice variation in perforations. (*b*) Italian Vitagraph intertitle on Kodak film made in 1924: more rectangular perforations. (*c*) Pathé edge marks. (*d*) Ambrosio edge marks. (*e*) Possible date code on edge 'barrel' perforation. (*f*) Lumière perforation

Many sources of technical data exist – nowhere near as complete as the data on cinema production, or on the content of newsfilms collections. The data is fragmentary, sometimes second- or third-hand and often difficult to locate. The bibliography to this publication contains as complete a list of references on films, manufacturers, laboratory practices and colour systems as possible. Unfortunately in many cases these publications are few and well scattered, and many archives and restorers will find access to them difficult.

9.4.1 Gauges, perforations and image ratios

In its almost 100-year history, the cinema has seen the appearance (and rapid disappearance) of a large number of film widths, differing in dimensions, images and the number of perforations. Most of these gauges are obsolete today and the equipment for preparing them or projecting them no longer exists. Some film archives have large collections of films in non-standard gauges.

The two principle gauges now used in professional cinematography are 16 mm and 35 mm. The form and dimensions of the perforations were standardized in the 1930s for both the gauges.

Perforations are a useful guide to date for the earliest films but after the 1930s the two 35 mm and one 16 mm standards prevailed, and in reality by 1920 the perforation type is really of little help in dating, except in a few specialist systems.

Images vary in ratio on the 35 mm or 16 mm film and these two may provide clues.

9.4.2 Edge data

There are three types of information to look for:

- special identification marks put on the copies by the production company;
- special identification marks of the raw stock manufacturers;
- special frame numbering sequences, on negative film and some prints, put there by the laboratory.

Special identification marks put on the prints by the production company

In the first 20 years of cinema history the main studios had very precise marks for their products. This discouraged copying – one of the first anti-piracy methods – and served as a recognizable symbol for buyers. The cinema was in its beginnings and every studio had established special techniques that were guarded jealously. Therefore their films contain a series of signs that often help in discovering the producer.

The bible of these early edge marks is Harold Brown's *Physical Characteristics of Early Films* (1990), published by FIAF.

Special identification marks of the raw stock manufacturer

While special marks made by the film producers on the film margins disappeared almost completely by 1920, those of the raw stock manufacturers are still in use today.

It has for many years been the custom of film stock manufacturers to produce a latent image of their names and often other marks on the edge, beyond the 35 mm perforations, of their films. These are processed as images during development. Some edge marks are stencilled letters not latent images. These marks are sometimes very faint, and if the printer exposes the entire width sometimes the edge marks from previous elements can be printed through to the print film and need to be looked for.

Example of film edge data – Kodak

The practice appears to have commenced in 1913 with the Eastman Kodak Company, who then printed the word 'EASTMAN' in large stencilled letters on one margin. This style was continued until about the middle of 1914 when the lettering was changed to a smaller style, and a dash was included two or three frames from the name. This continued throughout 1915. In the early part of 1916 the films had two small dots in place of the dash.

During 1916 the Eastman Kodak Company began a systematic series of the year symbols on their film stocks made in Rochester, USA, in a manner somewhat like the hallmarking of silver. A comparable series of marks on stock made at Harrow, in the UK, was begun in 1917. Stock made by Kodak in Canada from 1925 onward used another similar series of

THIS IS A DATE CODE CHART FOR EASTMAN KODAK MOTION PICTURE FILM. READ THE SYMBOLS ON THE EDGE MARKINGS OF THE FILM FROM LEFT TO RIGHT, AND COMPARE TO THE CHART. THIS WILL TELL YOU WHEN THE FILM WAS MANUFACTURED AND WHERE. WHITE PRINTING TELLS YOU INFORMATION ABOUT THE NEGATIVE, AND BLACK PRINTING TELLS YOU INFORMATION ABOUT THE POSITIVE PRINT. EXAMPLE: THE BLACK PRINTING READING LEFT TO RIGHT ON A PRINT OF "THE PRODUCERS" IS " + + ". THE CHART TELLS US THAT THIS IS A PRINT STRUCK IN 1968, WHICH INDEED IS WHEN THE FILM WAS RELEASED.

FOR FUJI FILM, THERE IS A 4 DIGIT CODE ON THE PERFORATIONS. THE FIRST 2 NUMBERS ARE THE YEAR THE FILM WAS MANUFACTURED. FOR EXAMPLE "8 3 J M" IS A PRINT MANUFACTURED IN 1983.

EASTMAN KODAK DATE CODE CHART					
1922	1942	1962	● ■	1982	● ■ X
1923	1943	1963	● ▲	1983	X ▲ X
1924	1944	1964	▲ ■	1984	▲ ■ ▲
1925	1945	1965	■ ●	1985	■ ● ▲
1926	1946	1966	▲ ●	1986	▲ ● ▲
1927	1947	1967	■ ▲	1987	■ ▲ ▲
1928	1948	1968	+ +	1988	+ + ▲
1929	1949	1969	+	1989	X + ▲
1930	1950	1970	▲ +	1990	▲ + ▲
1931	1951	1971	● +	1991	X + X
1932	1952	1972	■ +	1992	■ + ▲
1933	1953	1973	+ ▲	1993	+ ▲ ▲
1934	1954	1974	+ ●	1994	+ ● ▲
1935	1955	1975	+ ■	1995	+ ■ ▲
1936	1956	1976	●	1996	X ● ▲
1937	1957	1977	■	1997	X ■ ▲
1938	1958	1978	▲	1998	X ▲ ▲
1939	1959	1979	● ●	1999	● X ▲
1940	1960	1980	■ ■	2000	■ ■ ▲
1941	1961	1981	▲ ▲	2001	▲ ▲ ●
ONLY EXCEPTION 1948 CAN BE EITHER ++ OR ●●●					

WHERE STOCK WAS MANUFACTURED

S•AFETY – ROCHESTER
SA•FETY – CANADA
SAF•ETY – ENGLAND
SAFE•TY – FRANCE

Figure 9.3 Recently produced flyer from Sabucat Productions, California, illustrating the Kodak date marks

marks. In the late 1940s this information was given by Kodak to the National Film Archive, in the UK – originally confidentially, but subsequently generally released.

No such marks were put on the stocks made by Kodak in France and Germany during the 1930s. French stock was marked simply 'Kodak France' and German stock, 'Kodak A.G.'.

In 1927 Kodak took control of the Pathé film stock factory in France. Thereafter, the Pathé stock was still marked with the name 'Pathé', but the Kodak UK symbols may be found on it as well.

The USA system of symbols repeats every 20 years, the UK system repeats every 19 years and the Canadian system every 11 years.

9.5 IDENTIFYING THE ELEMENT

9.5.1 Introduction

The term **element** is used here to define a stage in the sequence of production of a motion picture film. A camera negative, a projection print, a duplicate negative, a sound negative, a B roll cut negative are all elements and can all be elements of the same production. In English or American laboratories traditional jargon terms for each 'element', such as 'mute' for the camera negative and 'track' for the sound track are widely used, and the term element is not well known. **Element** is a useful general term and will be used here because there is no other equivalent.

Identifying the element can be very important in planning the sequence of events of a restoration. However, it is just as true that identifying the element may not be as quick or easy as it seems; a duplicate negative that has been carefully and well made can look very much like the original negative from which it is taken.

A useful technique is to look at the perforations of a film – sometimes it is possible to detect around them images of previous film perforations printed through by contact printing. As many as five images have been seen indicating the image is the sixth generation at least!

The following is survey of the main types of elements. Many of these, especially those that are used in the post-production phases (e.g. editing, mixing, synchronization, dubbing, titling, special effects etc.) rarely find their way into an archive. They are only used in the laboratory and, as soon as the work is finished, become useless and were usually lost or destroyed.

9.5.2 Positives

Projection prints are the most common material that is available to, or found in an archive, just as laboratories store the negatives and duplicates for their customers.

Subject → ORIGINAL NEGATIVE → POSITIVE PRINT

Both colour and black and white positive copies have a transparent base. Sound tracks were variable density until about 1958, and variable area from 1935 to today. Magnetic tracks were in the usual track position, and even 'magoptical' tracks exist, in which part of the optical track is overlaid by a magnetic stripe applied after the film was processed (usually for an alternative language).

Most archive prints are **release prints**, that is, they were produced for display in a cinema and were one of many that were originally produced from the original negative until about 1925 but from duplicate negatives thereafter.

Prints with frequent joins at scene changes were 'pos cut' and were pre-1930; those in one piece were 'neg cut' and were from about 1925 to today.

More rarely the print will be an **Answer print** (or **first trial print**). This is, literally, the first graded copy printed from a cut negative; it was often thrown because it usually needed to be further corrected to satisfy the requirements of the producer. Answer prints in colour, especially those produced before the use of Video Colour Analysers in the laboratories, could be a far cry from the quality of the final copy. Originally they would be the first trial and error print made. The only way of identifying answer prints, if there isn't anything written on the can or at the end of the film, is to evaluate the quality, if possible by comparing it to another copy. However this may not always be helpful. Technicolor release prints could differ remarkably from each other, as the early systems were obviously not very repeatable. Some laboratories made 'answer prints' with no sound.

Even more rarely found is the **show print.** This was the final print made by the laboratory with all the grading corrections, and was often used for the first private shows, for premiers or as a selling medium. Most ended up with the producer or the director in their private collection!

Rushes (called **dailies** in the USA), are rolls of prints just as they were produced from the original negative as soon as possible after the shooting (and seen by the camera crew 'daily'). They vary in grading considerably. In the 1930s, and in the early days of negative/positive colour in the 1950s, they were often of poor quality. However, by the 1970s the quality was high. Rushes are rare in archives. They can usually be recognized if they are from a feature film production by being silent repetitions of the same scenes shot again and again.

Rushes were generally cut up and joined to produce an edited story called the **cutting copy**. This is usually very easily recognized. The rushes or specially requested new sections of print from the camera negative were (and still are today) joined, often simply by tape but before the 1960s by conventional splices, to put together the story of the final production by the editor. The positive prints are almost always written on (in pencil or crayon) to give special instructions to the negative cutter who will later join all the original negatives together to make the **original negative** element of the production. Sometimes lengths of white spacing, with written or coded explanations for special effects, are cut into the prints. These are sometimes much longer than the final film and were not intended to indicate the real length. Cutting copies are often very badly scratched and marked, even torn and dirty. They were always silent.

Once the editing phase is complete one has a **workprint**, a positive copy spliced with tape or glue, the result of the editor's work which serves as the basis for cutting the negative. Usually the quality of the workprint is quite bad, due both to the printing as well as to the fact that it is often scratched, dirty and torn. It can be useful in reconstructing the original editing. Sometimes a workprint was made crudely and cheaply from the cutting copy by printing onto reversal film.

Occasionally **rushes out-takes** are found. These are rush prints of scenes that were not used in the production and were frequently put back into the can in short lengths with or without rejoining.

9.5.3 The camera negative

This is easy to distinguish from a duplicate negative because it does not have any of the signs of having been produced by a printer. A step printer produces a darker or lighter frameline between the frames; a continuous printer produces a difference in density, sometimes very slight, between the exposed parts (the transparent frameline) and the unexposed parts (for example, the borders and the edge areas between the perforations).

Original negatives have the following features:

- No border around the frame of any sort.
- The edge density between perforations is exactly the same as the density between the frame lines.
- No 'septum lines' of any sort – these are thin straight lines of density produced in a printer by masks and gate apertures of one sort or another not coinciding precisely and occur outside the frame area.
- If it is an edited negative it will have a splice between each shot.

It is almost always possible to identify non-edited material; these could be rushes that have not been edited yet. In this case it essential to know if the film has never been finished or if, on the contrary, it has been; then the non-edited material that you are identifying will most likely be rushes material that was never used and was termed **negative out-takes**.

Some laboratories use the term '**cuts and trims**' for cans of negative or rushes prints that have not been used in a production. It is not uncommon for producers to sell the cuts and trims to film stock shot libraries, after the editing is over, and cans containing several small rolls of scenes, original negatives and prints mixed up together in the same can will probably come from a commercial company such as this. This library material is often well used!

Sometimes cuts and trims are in loose rolls in which the individual lengths are not joined but simply interleaved in to make what is sometimes called a '**peeled roll**'. This is done by both editors with rush print out-takes, but also by negative cutting companies and laboratories during the negative cutting operation. A peeled roll of negatives is a good sign that the material is probably negative out-takes and has not been touched since the production was made.

9.5.4 Black and white duplicate negatives and internegatives

The other possibility, given that you have a negative, is that it is a duplicate negative of an original in black and white or in colour. In the preceding section you saw how an original negative can be distinguished from a duplicate. Duplicate negatives can either be combined, i.e. they contain both the scene and the soundtrack, or separated, in which case the soundtrack has been duplicated or re-mastered separately. Duplicate negatives have all the indications of being printed and:

- most frequently have negative perforations (BH type);
- often have a coloured base – blue, purple, lavender;
- frequently have sharp lower densities on the edges between the perforations;
- often have dark septum lines (see above);
- are usually denser than original negatives (this produces a better subjective quality), but this is not always a good guide;
- often have images of previous generation perforation around the perforations, but only if printed on certain printers;
- have no joins between scenes.

The last clue is the best, as the absence of a join between markedly different scenes is a sure sign that the element is a duplicate of original negatives that have been joined together.

Nowadays the quality of duplicates can be very good, especially if they have been made from dupe positives or interpositives made on special duplicating stocks. However, prior to 1926, when Kodak introduced the first film designed solely for duplicate negative production, the quality of the duplicates was not very good. They had a higher contrast than original negatives and a notable loss of definition.

In order to produce a duplicate or copy negative from an original negative the most common method used since the turn of the century is to print the negative to make a positive and print the positive to make a negative from this.

Subject
→ ORIGINAL NEGATIVE
→ PRINT
→ DUPLICATE NEGATIVE

Until about 1926 only two types of film stock were made, camera negative and projection print, although by varying the development time the contrast could be altered within certain limits. If a copy negative was required, there seems to have been two ways of doing this.

1. To use the **projection print** as the master, and make a copy negative from it onto camera film. To do this and keep the contrast down was not easy and the resulting duplicate negative was often higher in contrast than the original negative.
2. To use two stages of camera film printing from the original negative. This could be used to produce quite good results from the very earliest times but was rarely done as the safelighting used to print onto camera film was darker and so printing was an awkward procedure.

Some film companies which needed large numbers of duplicate negatives continued to use a modified version of the first method but with quite acceptable lower contrasts until as late as the 1950s, in order to avoid purchasing the expensive duplicating stocks. They produced a **special low contrast print** (by underdeveloping normal print film) as an **interpositive**. Newsreel companies especially did this; they used duplicate negatives as a library of material for cutting into later issues without destroying the original programmes so that most newsreel issues consisted of a patchwork quilt of new negative and duplicate negative. A good example was the British Pathé Newsreel company.

The majority of duplicate negatives made after the early 1920s were made using specialized duplicating film stocks and by the mid 1920s most stock manufacturers made them. The sequence of stages was substantially the same as before but using the new low contrast blue-sensitive duplicating materials.

9.5.5 Black and white duplicate positives, interpositives or master positives

Subject
→ **ORIGINAL NEGATIVE**
→ **MASTER POSITIVE**
→ **DUPLICATE NEGATIVE**

Master positives used as duplicating stages can be recognized as such only after the early 1920s. Thereafter most master positives were intended for duplication only and did not have a dual function and were not acceptable as projection prints. Most had negative type (BH) perforations and were visually lower in contrast, with markedly low density blacks and sometimes grey or coloured bases. All three terms above are used in different laboratories but all refer to the same element.

9.5.6 Colour duplication elements

Prior to the introduction of tripack materials and colour development, the duplication stages of colour processes were difficult to identify without detailed knowledge of the process as a whole. However, Kodak started to introduce colour duplication materials in the 1950s, and recognizing colour intermediates after this is quite easy.

Initially and until today the most extensively used system uses Eastman Colour Intermediate film for both stages of duplication; for the preparation of the interpositive and the duplicate negative.

Subject
→ **ORIGINAL COLOUR NEGATIVE**
→ **INTERPOSITIVE**
→ **DUPLICATE NEGATIVE**

A colour duplicate negative is recognized by all the characteristics listed above for recognizing a black and white duplicate negative except that the base colour is orange due to the integral masking. A colour interpositive is unmistakable; it is a low contrast, low density positive with an orange suffusion due to the orange integral masking. The perforations of this material are always BH. 16 mm versions of this system do exist but are rare. Colour intermediate graininess and sharpness is not good enough for 16 mm.

Another system first introduced at the end of the 1960s uses a single stage and a reversal duplicating material also from Kodak called CRI or Eastman Colour Reversal Intermediate (CRI). This material was used until the early 1990s but is now almost obsolete as the new versions of Colour Intermediate improve in sharpness.

Subject
→ **ORIGINAL COLOUR NEGATIVE**
→ **REVERSAL INTERMEDIATE NEGATIVE**

This material is significantly finer in grain and sharpness than most intermediate materials but very critical to process. It is made in both 16 mm and 35 mm.

A CRI duplicate negative is immediately recognizable by the black reversal type surround to the image that includes the perforation areas.

9.5.7 Confusing terms used for intermediates

The labels on the outside of cans of black and white or colour intermediates or duplicating elements can be confusing and misleading. In the English-speaking world of the USA, England, Canada and Australia many different terms are used for duplicate negatives and intermediate positives. Not only are there national differences but also major differences between companies, especially the laboratory companies, some of whom have developed their own semi-technical jargon, particularly with respect to duplicating.

Some of the terms used are:

Intermediate – a general term that could refer to almost any stage in duplication that is not the original negative or a final print or simply mean that the film stock used is Eastman Colour Intermediate.

Internegative – a term used for an intermediate negative made from a positive. This could have been a positive print or a reversal original. In some laboratories it means a duplicate negative. Other laboratories use the term solely to mean Eastman Colour Internegative

- **Duplicate negative = dupe neg = intermediate negative = copy negative** – these terms are all synonyms.
- **Duplicate positive = interpositive = intermediate positive** – these terms are all synonyms.
- **Lavender** – originally lavender-coloured base B/W duplicating film from Eastman Kodak in the 1930s. Can refer to any duplicate negative.
- **Fine grain** – after the lavender film was discontinued until the present, a series of film stocks called Fine Grain Duplicating film have been released by Kodak for producing duplicate positives and negatives. Hence in many laboratories duplicate positives and duplicate negatives are called **fine grain pos** and **fine grain neg**. This slang usage has existed from the 1940s to the present day.

9.5.8 Other materials

Included among the film materials that might find their way into an archive are all the materials used in the production of titles, credits and special effects. These are negatives or positives destined to be passed through an optical printer and recombined in various ways so as to achieve the desired result. There are background or foreground images for credits, credits to be edited by superimposing, short sequences of intermediate materials incorporating simple effects such as fades dissolves wipes or other special transitions from scene to scene – a multitude of different elements.

If dealing with a silent film, you might find entire reels of positive intertitles that were inserted only at the time of editing the positives.

Some special effects involved quite elaborate intermediates but these can really only be identified by specialists in special effect production.

9.5.9 Colour separations on black and white stock

Colour separations were made for a number of different reasons:

1. Colour separation is a safe system for the preservation of colour negatives in a more permanent state than as dye images and these are recognizable by being three separate rolls of identical black and white positive images with differing tonal renderings. The positive images appear low contrast and high definition and with negative perforations.

   Generally these films have all the characteristics mentioned above, of duplication.
2. Negative separations in two or three separate rolls that have the characteristics of original negatives are usually camera originals. It is not always possible to identify for certain what colour system they were used for, since both bipack and

tripack camera systems were used to produce separations that were printed by a number of different methods.

3. Negative separations with the characteristics of duplicates (see above) can be from a wide range of origins. The commonest are separations made from a colour reversal original. For example, even as early as the late 1930s reversal Kodachrome was used as the original camera stock for a Technicolor print process.
4. In a few rare cases the separations were made on a single strip of film with the red, green and blue separation images in sequence, called **sequential frame separations**. Original negatives in this form will probably be animation film shot as single frames. Duplicates will be prints from these originals or may be from a wide range of less common systems.

All separations should be examined by a specialist in colour systems.

9.5.10 Reversal materials

Reversal materials are those film stocks processed to a positive image in one processing stage. Some films processed by reversal have negative images: for example, an image from a negative printed onto a reversal film will be a negative. Colour Reversal Intermediate is a stock designed for copying negatives in a single stage, but generally reversal films are either camera original materials or are for copying existing positives.

Recognizing reversal film is straightforward: in a reversal film the parts **not** exposed by the light are dark (in other films they are clear). The unexposed parts of the film, for example the borders, the space between the perforations and the frameline itself, are dark, whereas in all other films they are transparent.

Reversal film was originally used for filming anything that did not require a negative in order to make a number of prints. Today black and white reversal is extremely uncommon and restricted to certain scientific use, but from the 1940s to about 1980 black and white reversal was widely used by colleges and small industrial film units. Colour reversal films are mostly non-professional or for specialized use, such as high speed photography or satellite recording, or are special high speed, fast process stocks for television news and current affairs. Over the past few years this use has diminished rapidly in favour of electronic news-gathering techniques or colour negative.

9.5.11 Colour reversal print systems

Several manufacturers made low contrast reversal camera original films which were designed to be printed. The camera original film was never projected but was treated as a printing master (just like a negative). The lower contrast of the camera stock resulted in a better exposure latitude than projection contrast films. All these were colour systems and a good example in use for over 30 years was the Ektachrome Commercial system from Kodak. Gevaert had a similar system.

9.5.12 'Direct' positives (and negatives)

For printing purposes, but especially for producing positive copies from work copies during editing, when cost is important and quality not important, several other film materials exist (or existed) to produce a 'direct' positive without using the complex reversal process. Sometimes a low quality duplicate negative was (and still is) made by this process. Most of these elements will appear to be reversal images with black areas outside the image. Some of these materials had quite bizarre chemistry and were not silver salt based technology at all. A notable system with a short but erratic life was MetroKalvar, in which the image consisted of bubbles of gas in the film matrix! The more conventional 'diapositive', or 'direct' materials on the market today are all silver based and use a simple negative type film process to yield a low quality and often low density image. These direct film stocks were probably first introduced in the 1960s.

The process, in graphic English laboratory jargon, results in a '**slash**' print, or '**slash**' dupe. 'Slash' is also used by some laboratories to mean any cheap and cheerful print of dubious quality. For readers less familiar with English slang, 'slash' has a host of meanings, all derogatory and some vulgar!

9.6 SOUND ELEMENTS

9.6.1 Identifying different types of print soundtrack

Sound is present on positive projection prints as an optical track, as a magnetic track, or even as a combination. In order to reach this 'combined' state sound has almost always been recorded as a separate element, edited and transformed into the required format and only combined at the last printing stages. Sound elements most likely to be discovered include magnetic originals, magnetic edited versions, optical sound negatives or optical sound positives.

In some cases, in order to produce a 35 mm soundtrack at lower cost, a 17.5 mm wide film was used, which is a 35 mm slit in two lengthways; so it has only one line of perforations, exactly identical to those of the 35 mm negatives.

Details of sound tracks are to be found in the chapter on sound restoration and in Part 1.

Magnetic sound track made its appearance in distribution copies with the advent of CinemaScope in 1955, introduced by Fox with the film *The Robe*. CinemaScope not only used an anamorphic lens to project the picture onto a wide screen, but provided stereophonic sound as well. This was made possible by the placing of four magnetic tracks across the film. Since they were completely separate, each one provided sound to different speakers that were strategically placed in the cinema hall. (The disadvantages of magnetic sound were mainly connected with the fact that the four tracks were applied or 'glued' onto the film after its printing and developing and then had to be recorded, which significantly lengthened, complicated and increased the cost of the film laboratory work.) Tracks tended to become unglued, demagnetized and, with use and the passing of time, lose the metallic layer of the track. Finally, not all cinema halls were ever re-equipped to handle magnetic sound, so copies were distributed that had both a single combined optical sound track as well as the four magnetic tracks. Slowly, the four magnetic tracks disappeared.

Stereophonic sound has returned to the cinema with the modern Dolby system, which used an optical sound track. A Dolby stereo copy can be identified only by looking very carefully at the sound track. It can be seen that the four tracks are not absolutely identical, as they would be in a mono sound track.

Magnetic sound on film returned to be very successful from 1966 until the late 1980s when magnetic sound tracks were applied to 16 mm reversal colour film used for news and current affairs. This was applied after slitting the raw film. Kodak's Ektachrome EF and VNF films were the most widely used.

Some 16 mm prints made with double bilateral tracks have, in the past, been 'post striped' with a narrow magnetic track covering one of the track images. This can then carry a different sound track from the optical. This system was used for two languages by several training film companies and by inflight movie companies during the 1970s. These prints are sometimes called MAGOPT prints.

9.6.2 Identifying sound-only elements

Separate sound elements are easily distinguished from picture elements – they are either magnetic tracks or have optical track images and no images. Some 35 mm, 16 mm and 17.5 mm was perforated and coated entirely with magnetic coating. Most 35 mm and 17.5 mm film was perforated and striped in the regions of use rather than all over and appears as clear film with linear stripes of coating.

A sound negative film element has a negative sound track in the sound position. The central area of the track will be low density, and the outer areas high density. The base is usually coloured or grey. If there are many blooped joins this could be an early original negative (pre-1953 approx.). If it has many scene changes and no joins this is a final track, probably made from a magnetic master if after 1953.

A positive film track on clear film with no picture and a high density image is probably a pre-1953 editor's work track (or a mistake by a laboratory that forgot to expose the picture!). Labels on cans are often very important in estimating what sort of sound a can contains and a lot of local laboratory terms have been used. Some useful ones to know (in English) are:

- **M+E** Music and effects – usually a track of all the mixed sound excluding the dialogue.
- **Mute** Not what one might expect. This refers to a picture negative for which there *is* a sound track roll.
- **Track** The sound track roll that goes with a mute.
- **Silent** This means there is not a track to go with this picture.
- **Sync** followed by an instruction: **Level** or **24 frame** etc. This indicates how a sync mark on the picture negative leader relates to a similar mark on a track roll leader, to assist an operator to get the two elements in sync. The presence of these instructions on a negative can, or the presence of the sync marks themselves, usually a big crayon X or S, or a hole punched in the negative leader, indicates that somewhere there is a sound element.

10

Principles of film restoration and film reconstruction

10.1 INTRODUCTION

In the past 20 years, many restored and reconstructed versions of great films have been presented and have attracted the attention of large audiences. Among the first were *Napoleon* (dir. Abel Gance; 1927), reconstructed after a life-long research by Kevin Brownlow; *Intolerance* (dir. D.W. Griffith; 1916), with the original tinting restored by Raymond Rohauer; and *Metropolis* (dir. Fritz Lang; 1926), reconstructed by Enno Patalas. It was after these three reconstructions that a larger interest in the problems and principles of film reconstruction arose. In particular Patalas' archivist reconstruction of *Metropolis*, which took a stand against Giorgio Moroder's commercial re-issue of the film with a contemporary, typical 1980s soundtrack, had pointed out the need for some principles of film reconstruction.

In general terms it is possible to distinguish different 'kinds' of film restorers. There is the archivist restorer, working as a kind of archaeologist on the materials, trying to reconstruct the history of a print and the production process of a film. Or there is the artist–restorer, using the old materials as a source for a new product, sometimes with respect for the old materials without damaging these physically or intentionally, but sometimes also intending to make something completely new and personal without any respect for the original materials. Or there is the commercial entrepreneur restorer who just wants to make money with an old film, without taking into consideration elementary principles of preservation or moral conduct with regard to restoration and reconstruction.

Within FIAF, archivists have discussed these problems and principles during the 1980s and 1990s, and although no fixed set of rules or a code of ethics of film restoration has yet been established, a general awareness among film restorers with regard to ethical principles, applicable to both film restoration and film reconstruction, is very strong now. In addition, FIAF recently formulated its own code of ethics with regard to the rights and duties of film archives in more general terms. From this code it becomes clear that FIAF archives see themselves more and more as equivalents of other museums and archives which do have applied codes of restoration ethics from, for example, ICOM (International Council of Museums), AIC (American Institute for Conservation of Historic and Artistic Works) or ECCO (European Confederation of Conservator–Restorers' Organisations). This chapter has been written from the point of view of film archives that do not want to distort the nature of the original material or the intentions of its creators.

At the beginning of this book the distinction between restoration and reconstruction was made. While 'restoration' refers to visual quality of the image, 'reconstruction' refers to a philological activity of putting the programme or narrative – below referred to as the 'text' of a film – back to something like an 'original'. Since restoration can alter the quality of an image considerably, it is important to keep in mind that both activities, restoration and reconstruction, are subject to an ethics of restoration.

The main emphasis of this book is on the technical aspects of film restoration, but this chapter will demonstrate that film restoration cannot be done merely from a technical point of view. It is also an activity of interpretation and opinions, of taste and editorial decisions; it can also be influenced by prosaic circumstances like practical or financial restrictions. Along the route of a film restoration decisions are made all the time, decisions that can influence the final result and the quality of the restoration process considerably.

Due to the technical complexity of the restoration process, film restoration and film reconstruction can never be done by just one person. However, in the end, only one person should be responsible for the final result. For this person technical facilities and possibilities are the instruments which help him or her to reach their goal. Therefore, for the decision making process, a good knowledge of film production and laboratory processes, as discussed in this book, is fundamental.

The responsible person is generally called the *film restorer*. This chapter will give an overview of the work and responsibilities of the film restorer. It is also an attempt to provide the restorer with a set of principles for restoration and reconstruction.

10.2 THE FILM RESTORER

Every film has its own unique set of problems and it is therefore impossible to give a definite set of solutions for every situation. A restorer of a film must be able to identify these problems, must be able to interpret them, and to make the necessary decisions following a set of principles, sometimes of a technical nature, sometimes of a non-technical nature. It is therefore necessary that a film restorer knows the technical principles of the restoration process very well, can make decisions for the correct conservation routes, for the right choice of film materials, and can foresee the quality of the final results. The restorer should be able to discuss these technical aspects with the laboratory and therefore should be familiar with most of the techniques discussed in this book. The laboratory technicians will have a greater ability and experience than the restorer in their specific sectors of operation. However, the restorer should be able to recognize the potential of the original material available and the photochemical process. The restorer should be able to choose the right duplicating route and be able to judge the quality of the duplication work. Therefore the film restorer must be familiar with most elementary duplicating routes. In particular, in film reconstruction, it is often necessary to use a combination of duplicating routes. This can be due to technical reasons, for instance when a film exists in an archive as an incomplete negative, and also partially as a print.

But film restoration is not just a technical issue. Non-technical considerations are a substantial part of the labour of film restoration and film reconstruction. Sometimes practical or financial problems may affect the decision making process. In these cases the film restorer has the cultural responsibility to work to the highest standards and not to compromise. More complicated, however, are the historical and more philosophical considerations, for which the restorer or archivist cannot consult a laboratory technician. On the contrary, on these issues the film restorer should have a clear view and share this view with all other people involved in the restoration process.

A film restorer who wishes to respect certain principles will also have particular technical demands. In the past, ordinary commercial laboratory practices could not fulfil these demands and therefore many film archives have, in the past, started their own laboratory in order to be able to handle shrunken films, to adjust non-standard chemical processes, or to apply other unconventional procedures. Today some of these in-house archive laboratories still exist, but several commercial laboratories also now specialize in film restoration.

10.3 THE 'ORIGINAL' AND OTHER VERSIONS

Films exist in different versions and editions. This is true for the silent period in particular, but even today dubbed versions, abridged versions for television and other versions are still made. Among film restorers an overriding principle became accepted, which was to establish which version of any given film should be restored. Every alteration to a film, whether textual or technical, must be considered in relation to the definition of the version that the restorer is going to restore. In order to define a given edition of a film we must be able to reconstruct the text, based on all the available historical information. All the data has to be compared and its reliability verified. Every intervention carried out has to enable further interventions, and every action must be reversible and documented. The demand of reversibility means in film restoration that nothing of the original material should be altered in such a way that the restoration cannot be done again. 'Reversibility' in film restoration means therefore 'repeatability'.

There could be many editions of a film, and there could be many reasons for this. The first are production characteristics. For instance, as we shall see below, in the silent period films were made with different cameras at the same time. But also in later years different version of films are not uncommon. Another reason could be that the film maker has made alterations. Some film makers tried to improve the film all the time and therefore a film was never completely finished. Thirdly, censorship was an important factor in altering films. Sometimes films were intended for a particular market. Pre-Revolutionary Russian films that had a tragic ending for the Russian audiences got a happy ending for the foreign market. Or a film was lavishly coloured for the internal market and very simply coloured for the foreign market.

In the silent era there were often more negatives because duplicating film materials did not exist and because second negatives were needed to send to another country for foreign distribution. If there was only a single negative, only a limited number of copies could be produced and then it had to be thrown away when it became damaged. The easiest way to produce more negatives was by having more cameras running at the same time, or to re-shoot entire films. A good example is *Rescued by the Rover*, first made by Cecil Hepworth in 1905, when films were not distributed but sold directly by the producer to the cinema halls. *Rescued by the Rover* was a great success and the producer printed so many copies that the negative could not be used any more. Hepworth was forced to shoot a second version and again, a few months later, a third. *Rescued by the Rover* narrates the exploits of a dog (Rover) that saves the life of a little girl. Due to the fact that the three versions were made a few months apart, it is possible to note that the young actress has grown quite perceptibly through the three versions of the film. If one wants to restore *Rescued by the Rover*, it is necessary to decide first of all which of the three versions is to be worked on. Mixing shots from the various editions would create a film that, in fact, never existed.

Establishing the aims of a restoration/reconstruction means not only that criteria for version or edition should be determined, but also the characteristic qualities of the image: format, contrast, density and colour. It is not sufficient to say that a restorer will, or must, restore the 'original' version, since there could be many concepts of the 'original'. Also a censored version of a film could be considered as an 'original' version, since it is that version that was seen by the audiences. In general terms, the options available to the restorer are to restore:

1. The film as it is in the restorer's hands.
2. The film as it was seen by its first audiences.
3. The film as was seen by later audiences.
4. The film as it was intended by the film maker(s).
5. A version that is meant to be seen by a modern audience.
6. A new version, a reworking of the original version through a contemporary artist.
7. A version for commercial exploitation.

In deciding which version to restore, it is important that the restorer's considerations are registered in the documentation of the restoration. This documentation should not only contain all factual actions and interventions on the material, but also the motivation and argumentation for decisions made during the restoration.

10.4 RECONSTRUCTION

Everybody who works on the restoration of a film is aware of the concrete, tangible and material quality of a film print. With this physical reality the film restorer works every day, using both hands and eyes. He knows how important it is to 'read' a film print not only on a narrative or content level, but also on a concrete, material level. Splices, different kinds of filmstock, frame lines, even scratches can give essential information for the restoration process. It is not exceptional for instance that on a narrative level it seems that frames are missing, while in the print no splices can be found. When the print is a first generation print, then it is very likely that the film has always been shown this way.

The tangible aspect of a film is always kept hidden from the spectator, who knows only the other side of the life of a film – when it becomes cinema by being projected on the screen. Reconstructing a film means working on both the material reality of the film, as well as on the visual and content appearance on the screen. This means that when we speak about the reconstruction of a text, we do not merely speak of a jigsaw puzzle of pieces and fragments in order to make something as complete as possible, we want also to construct something that can be perceived in the minds of the spectators as something with a certain integrity. The work of reconstructing a film can only be done by working both on the film itself and on a concept of the final presentation at the same time. In the end a film only becomes alive when it is projected.

Reconstructing a film means to establish in the first place which elements and data are available. Usually a film restorer has to work with three parallel sources of data.

First, there is the film itself; sometimes there is only one print, but in many cases there is a lot of material. From film prints emerge two sources of data.

(a) on a content/narrative level
(b) on a technical level.

Secondly, there is all non-film information which can be compared with the information from the film itself:

(a) non-film materials related to the content or narrative of the film: reviews, brochures, leaflets, photographs and other documentation;
(b) non-film materials related to the production techniques of the film.

Thirdly, a film restorer will always work with a concept of the film as it appeared on the screen in the past and as the restored version will appear on the screen, since only in the projection will the restoration come to completion.

10.4.1 The film text

The preceding chapters looked at the identification of historical and technical data of a film. These data are fundamental for the work of film restoration and film reconstruction and are the necessary input for the decisions during the process of film restoration. Working on the film itself means, in the first place, to identify correctly the technical and historical data of a film. For the purpose of restoration and reconstruction a correct interpretation of these data is essential. A restorer should be very careful not to be too positive about his or her interpretation of the data without first looking at the documentation and also at the image itself. Too often the film tells one story but the documentation suggests another. Like today in television news or documentaries, also in the past, films contained materials from different periods. A camera image of 1905 can be duplicated in 1915, selectively enlarged and inserted into a drama of 1920, just because it was a picture of the bridge the director wanted. This happened for many years throughout almost all newsreels. For instance in a British Pathé newsreel of 1937, a duplicate negative of a 1918 sequence was spliced in because it showed a scene of Berlin.

Technical and historical data help not only to select the best materials but also to reconstruct a film. As mentioned above, splices, or the absence of splices, can tell something about mssing or inserted sequences. Edge marks, frame lines or colour systems may tell something about the sources of the materials. In all cases it desirable to have more prints available for comparison and also to search for negatives and first generation materials in order to obtain the best restoration quality possible.

In the text below the main emphasis is on silent films, since these films differ most from our contemporary film production techniques. The general problems are also applicable to sound films.

10.4.2 Reconstruction of silent films from positive prints

Positive projection prints are the finished version as shown in the cinema. Many of these films have defects because of intensive use. Moreover, in particular in the early days, a film was never considered as something of which the integrity should be respected. In the silent period it was very common that someone removed, replaced or inserted something. In many cases, however, no other material is available. If negatives are lost, a film restorer is very fortunate to find one or more prints which are from the period. The big advantage of these prints from the silent period is, however, that they are often coloured and that they still have their intertitles. And when the negatives do exist, positive material may still be of great value since these positive elements may serve as valuable references for the reconstruction of the film, in particular of colours and intertitles.

If several prints are used to make a final restoration it is important to determine the differences in image quality, colour quality, format, generation etc. Through interventions during the duplicating process it is possible to avoid the final restoration looking like a patchwork. It is therefore important to decide if a balance of image quality in the final restoration is desired, or not.

Intertitles

Original intertitles in positive prints and in their original language are usually in place. For use in foreign countries intertitles were most of the time replaced with titles in the language of the country of release. Sometimes these titles were made by the production company in the original country of production, often with mistakes in the spelling. When the titles were made locally, the films were exported with flash titles, titles of just a few frames, and the distributor could insert the titles on the places where a flash title appeared. Not all flash titles are originally from the period the film was produced. In some collections the intertitles of films were cut down to just a few frames in the 1940s and 1950s, probably to avoid the duplication of considerable lengths of titles and to save money.

If there are still flash titles in the print which should be restored, they will not be more than a few frames (normally three), of which two will be ruined by the join with the preceding and following sequences and therefore useless. Only one frame will remain, sometimes damaged as well. Therefore, in general, it will be necessary to remake the titles from scratch, trying to match as exactly as possible those of the original.

Reconstructing intertitles

Typeface and framework graphics are both very important. The intertitle is part and parcel of the image of the film and its graphics have the same value in the organization of the work and in every sequence. To prepare new intertitles using different graphics for the typeface and the framework from the original would be quite unacceptable.

Often the production houses had their own easily identified graphics style that was used in one film after another. On other occasions, for special works, artists were hired to draw suitable graphics for titles. This was so for many of the German Expressionist films and, generally, for many films from the 1920s onwards.

When titles are made today they are usually type set with desktop publisher software. The printouts are then filmed with a rostrum camera. This is a very practical and ecomic way to do it, but the final look has a quite different effect than original titles. While the original titles seem to be an organic part of the film, also in their small damages, their instability and image quality, new DTP titles appear as some kind of high-tech slides. The effect of a frozen slide is quite difficult to avoid, but it is only in recent years that interest in the authentic quality of intertitles has grown and interesting developments are to be expected.

The text is obviously of great importance in the comprehension of a film. However, if the only copy of the film available is a positive with intertitles in a foreign language and we want a restoration with titles in the original language, then we have to face the problem of re-translating the text back into its original language. If the production notebooks or the censor's authorization still exist the problem is solved. In the absence of these documents the translation must be done with great care. Sometimes literary texts exist on which the film might have been based and which can be useful in reconstructing the text of the intertitles.

If the translation of the foreign language version was done by the production company itself, then its name and trademark appeared on the intertitle itself. Cines, in Italy, even put on every intertitle, beside the production number, the initial letter of the version: F for French, S for Spanish, and so on. The small imperfections in the translations make it in this case even easier to retranslate the text back into the original language, recovering the original wording with greater precision.

Censor's marks

Sometimes the censor's interventions are indicated on the positive copy. For example, in the Danish copy of *Maciste all'Inferno* the censor cut out all the more audacious scenes that take place in hell. The cuts are clearly marked by the impressed stamp of the Statens Filmcensor, who restricted viewing of the film to those over 16. These indications can be very helpful in the reconstruction of the 'complete' text.

10.4.3 Reconstruction of silent films from original negatives

Silent film reconstruction poses particular problems not relevant to later sound period productions, with maybe a few exceptions. The problem comes with negatives as it was common to manufacture the various scenes or sections separately and assemble them by splicing pieces of print together. This technique was not universal but the different methods of producing intertitles, the scenes and the different colours made joins in the print inevitable.

Positive cutting after the negatives had been used to make separate rolls of print, and two other aspects of silent film production – the existence of intertitles and the tinting, toning and stencilling methods used to colour prints after processing – all determined the way in which negatives were stored.

Intertitles and negative rolls

The methods used by the different production houses varied. Many negative rolls had no intertitles, but only small crosses scratched onto the emulsion or written in Indian ink at the location the intertitle was intended. If this is the case, then only by finding the censorship documents or the production notebooks will it be possible to re-establish the text of the intertitles.

In other cases the intertitles were substituted by a short piece of film on which the beginning of the intertitle has been written by hand, sometimes in pencil. In this case, using the text of the intertitles you can at least verify if they correspond with the negative, or if there are conspicuous differences.

Un-assembled negatives

The other problem with the silent original negatives is that, frequently, they are found unassembled, perhaps in the form they were used to print the different scenes in the laboratory. There are two typical cases:

- Completely dis-assembled: in this case the film has been reduced to separate scenes after having been originally assembled in sequence.
- Scene by scene: in this case the film negative always existed as separate reels or scenes. Normally they will be found as a series of small reels equal to the number of shots in the film. Many early production companies used this approach.

Assembled according to the different colours

These negatives were not in scene order, but in colour effect order. In this way the laboratory was able to print all the scenes of the same colour at the same time, tint or tone them together and assemble them only at the end. The colour that was to be used was usually indicated at the beginning of each reel, in Pathé by a number.

Again using Pathé as an example, the negatives prepared in this way normally have a small number in the upper or lower corner of the first two frames of each shot so as to indicate the order of succession for editing. By separating the various sequences and following these small numbers it is possible to reconstruct the editing of the film.

10.4.4 Non-film material data

The non-film material includes scripts, shotlists and also the articles published when the film was presented in the past, the promotional material (photographs, posters, leaflets, brochures, catalogues) and the official papers that every state produces as part of routine control of the production (permission from the censor, reports, lists, accounts). Sometimes a score can be very helpful or even personal memories. It depends also on the goals of the restoration if the non-film materials of the very first presentation are of importance for the restoration, or documents of a later date within another context. For instance, the Sovjet film *Kain I Artem* was shown in Holland in a censored version – no propaganda and no suicide scenes. Thanks to a Dutch critic who was aware of these cuts we know that the incomplete print still existing in Holland is the 'original' version of the film as it was shown in Holland.

All these non-film data sources often survive even when the film has long since dissapeared. For instance, thanks to these documents it was possible to determine that of the silent period of Italian cinema, only 20 per cent has been preserved. The titles of all the 9,816 feature films that were produced in Italy between 1905 and 1930 are known. For each one at least something has been preserved: a newspaper article, a photograph, the script, the censor's permission, a poster, or we know the actors, or the success it achieved.

Documents can differ widely in their trustworthiness. While the censor's authorization has to be, by its very nature, a precise and reliable account of the film, a newspaper article can contain serious errors. And it is not always possible to collect enough elements to permit a reconstruction based on the documentation. In addition, it is too often the case that the historical documentation is itself scanty and fragmentary, so that it is not possible to establish beyond doubt what the original text should have been.

In these cases, when there is any doubt, interventions to a copy must be made in such a way as to be reversible, so that further restorations can be made later if new information becomes available. It is therefore essential to document every step of the operation very precisely so that later it will be possible to redefine some of the passages.

10.4.5 Appearance on the screen

To the immaterial effects belongs all the information in the projected picture that might be useful in the reconstruction. This has to be systematically collated, from the numerical order of the intertitles, to the language used, or the director's obvious style. To make use solely of the information seen on the screen is extremely dangerous. It takes no account of the history of the film, and even directors that have a well-defined style are often forced by circumstances to adapt their style to various requirements. This approach for reconstructing a film is only suitable as an adjunct to other information, or if it is supported by other documentation, such as mentioned below.

10.5 QUESTIONS OF RESTORATION QUALITY

As was said earlier, film restoration is essentially duplication and it is impossible to make a perfect copy of the original. Film restoration always creates a lacuna, a difference between the original and the duplicate. And then there are at least two ways to judge this lacuna, either by judging the gap between the actual source print and the new copy, or by judging the gap between the result aimed for and the result obtained. The aim of a restoration will be defined by the film restorer but can be determined by the restoration policy of the commissioner, for instance an archive.

It is important to distinguish the particular visual and aesthetic qualities of a film print. As we have seen in section 10.3, version or edition also refers to the characteristic qualities of the image: format, contrast, density and colour. It is important to recognize that a tinted silent nitrate film has certain characteristics, that it is fundamentally a black and white print with a tint that applies to the transparent parts of the image and not to the blacks. It also important to recognize the saturation of colours in a Technicolor print – as it is important to recognize the particular characteristics of a Perspecta stereophonic sound print.

In terms of restoration it is important not just to preserve the information of image and sound, but also these characteristic – aesthetic

– qualities of image and sound. And sometimes it is desired to improve the visual quality of an image, for example by increasing the contrast. If it is impossible to make something exactly the same, it may be possible to recreate something of the same effect as in the original, also when certain techniques or materials are not available anymore. It is evident that contemporary colour film stock has its intrinsic limitations which are not comparable with the characteristics of an original imbibition print, for instance. It is therefore important that a restorer is aware of the possibilities of alternative techniques: for example, that in the Desmet colour system instead of a colour internegative a low-contrast black and white dupe is made; or that films that are shrunken or fragile cannot be printed on a standard continuous contact printer.

For the film restorer these alternative techniques open the way to simulation or to recreation of original colours, or of original image quality, or of original sound. Sometimes this approach can be quite experimental and lead to new technologies that are not necessarily computer-based. In recent years the awareness has grown that this simulation approach, but also the use of digital restoration technology, can only be successful if we know exactly all the parameters that characterized the film prints of the period. However, the exact data are often not easily available and therefore there is now a growing interest in establishing a database with all kinds of technical data, for instance with all the recipes for tints and tones, or with all the film stocks produced from the beginning up to today and their characteristics. It will be to the advantage of film restoration itself, and to the benefit of historical research of film, that film restoration becomes the subject of a more scientific approach, and as soon as possible.

Lack of such a scientific approach constitutes the big difference between film restoration today and restoration practice in other arts. For instance, the Mauritshuis in The Hague recently restored two Vermeer paintings. These restorations were not only done in a dialogue with a committee of internationally renowned restorers and art historians, but also with institutes for atomic and molecular physics, with chemical research laboratories and with institutes for X-ray photography. In fact, X-ray diffraction analysis, ultraviolet light photographs, beta-radiography etc. are quite common in fine art restoration. Some museums, like the National Gallery of Art in Washington, even have their own Scientific Research Departments. In most film archives you won't even find a microscope!

The fact that art historians followed the restoration of the two Vermeer paintings indicates already that there is a long tradition of interest from art historians in the work of restoration. The quantity of literature on this topic is enormous. It is very eloquent that, for instance, the new problems which the restoration of contemporary art has raised have resulted in considerable academic debate. In film restoration this is very rare, although several archivists also have positions at universities. It is also suprising that the problems of film restoration or the history of film technology have barely been incorporated in academic film studies. This would be useful not just for archives alone, but also for film studies, as the study of original nitrate prints in recent years has already demonstrated that several aspects of film history will need revision.

10.6 THE DIGITAL FUTURE

The quality of the reproduction of the original image and sound will probably change radically with the new technologies: a reproduction may still not be perfect, but many aspects of it could come close to perfection. Problem areas are at the start and the end of the digital restoration process. The first demand to the industry is that digital scanners should be able to scan the shrunken and vulnerable nitrate prints, like a Telecine machine. When a traditional duplication is first needed for a digital scan many advantages of digital restoration are lost. The second problem is that the digital data will be recorded back onto ordinary film stock with its intrinsic limitations of, in particular, colour saturation.

If we concentrate on what is achieved at the workstation, it becomes evident that a separate theory of digital reconstruction is necessary. As we have seen above with non-digital alternative techniques, the approach for reconstructing the quality of the image itself is relatively recent. Too often the responsibility for a good reproduction has been left to the technician and in the future the technician – in the shape of a workstation operator – will become even more important. Up till now archivist–restorers were always able to control one way or the other the restoration process. They knew what they could demand and expect from the traditional laboratory, just because they knew the possibilities as well as the limitations of photographic duplication. But in the era of digital restoration it will become difficult to understand the possibilities and there will cease to be many limitations. Archivists will have great difficulty in 'directing' the operators, because the archivists will not always know what to aim for and what to demand from the operator.

Here it becomes evident that the concept of the 'orginal' in film restoration needs further elaboration. In the case of restoring the original image and sound, the 'original' is often still an abstract, theoretical concept. One can try to reproduce a Gaumont Chronochrome and the result may look wonderful, but how do we know what it really looked like and whether the restoration resembles the original? To know what to aim for, the concept of the original has to become very concrete, because with the new technologies for the first time a film can really be repaired in its smallest elements, image and sound.

If we consider 'original' in its strict sense, image and sound quality could become 'as new'. But then one should ask whether it is desirable to strive for a perfect rejuvenation of image and sound. Here we must make again the comparison with fine art objects. We have said that film is not an artefact that is restored, like a fine art object. But if film restoration is essentially duplication and the creation of a lacuna, with digital technologies the lacuna could be extremely small and therefore the repair of a damage, splice, scratch or deterioration, and even missing frames, is with digital technologies much more like restoring the artefact in fine art restoration. For a museum presentation this is desirable to some extent, but for researchers and future restorers this can create a great problem. It is absolutely imperative that a digital restoration can be analysed and done again from the start.

10.6.1 Ethics of digital duplication for access

Digital scanning of film images still takes an enormous amount of time and money. For access purposes, however, there is a practical and economical alternative: scanning on Telecine and storing the electronic video signal in a digital video format.

Telecine scanning will probably be a routine job. An archive or a laboratory will try to scan as many metres as possible, in order to keep the prices low or to maximize profit. It is therefore important to have some fundamental ethical rules for Telecine scanning.

Telecine scanning creates a digital duplicate format which has no direct reference anymore to the original and some data will always be lost (e.g. resolution). The alterations of image or sound made during the transfer can never be reversed or analysed in a rational way. It seems therefore imperative that a transfer will first be made as close as possible to the original and that subsequent 'restorations' are made on later generations of that digital duplicate.

This means that a 1:1 image duplication is recommended. If for instance VHS duplicates are necessary for access, then the speed can easily be adjusted. For professional use there is absolutely no problem. Modern editing devices as we know them today can make any speed adjustment required.

If a mechanical wet gate is not possible a noise reduction or 'electronic wet gate' is also something that probably should be avoided on the master tape. In general it seems that the loss of information is substantial, whilst the advantage is marginal. It is uncontrollable whether the noise reduction reduces only scratches or also other very small parts of the image and in extreme cases the image loses something of its sharpness and becomes 'woolly'. With grading, zoom and framing the image can be altered quite considerably. It is to be expected that an archive will say that no information should be lost in the duplicate and that grading must be done in order to come as close as possible to the archival print. This is more or less the same attitude as in traditional photographic duplication. One problem is, of course, how to compare the electronic image with the print and how to keep a certain standard when you play the image on a arbitrary monitor.

A second, extremely important, problem is when certain restoration activity is also involved, like dealing with faded dyes. Here again the concept of the 'original' turns up as well as the concept of restoration. For routine restoration/preservation some very general guidelines are necessary. For restoration, in the sense of getting as close to the original as possible or to a museological presentation copy, a completely different approach is necessary. Here we encounter the same problem as mentioned above: even archivists often do not know what to aim for.

10.7 DOCUMENTATION

Documentation of the restoration and reconstruction activities has been neglected for a long time in the field of film restoration. In the restoration of fine arts this is quite common, but only in the past few years have film restorers started to look for standardized procedures to document all acts of restoration.

Since film reconstruction is essentially a process where at the beginning and end two different elements are there, it is important to document all the interventions made during the process. This is important for historical reasons. Through this documentation anyone can study the original copy and it permits anyone to understand all non-historical (aesthetic, ethical) decisions made during the process. But there are also practical reasons. If necessary, and if the source materials are still available, a reconstruction can be repeated easily. Also, if restoration is re-done after many years, it will be easier to understand if and why certain interventions were made.

Every film reconstructor has their own way of documenting what has been done. Notes, graphics, designs – all kinds of systems are possible, using standardized concepts or not. In attempts to bring more unification to the ways film restorers describe their labour, the European Gamma Group has proposed a system using a spreadsheet. This was tested on the famous German classic *Menschen am Sonntag* and proved to be immensely valuable. (More details of this restoration are given in Chapter 21 and an example of the spreadsheet appears in Figure 21.1.)

In this example you will not yet find all the laboratory data: all the exposure values for every shot could be inserted, but also data with regard to filmstock, contrast, washing etc. Moreover this model could be used to document all kinds of characteristics of the original print: for example, description of the colours of films from the silent period, or objective colour references of these colours.

10.8 WORDS OF WARNING

Some of the errors of previous restoration work have to be seen to be believed and the list that follows is by no means complete, but represents just the more obvious mistakes found in a famous 35 mm British newsreel collection.

- Full frame images printed by contact onto Academy format.
- Full frame silent images printed full frame but with a sound track lamp blacking out one edge.
- Images copied so many times with slight optical enlargement each time that the image is now 50 per cent bigger and thus has lost image all round.
- Full frame silent images at 16 fps intercut with Academy at 24 fps.
- Interpositives used as projection prints.
- Black and white reversal copies on high contrast camera stock from projection prints (known as 'soot and whitewash' prints).
- Stories recut so many times without recording the changes that the original sequence is no longer recoverable.
- Continuous jumping of the image due to shrunk negative being printed by contact on a conventional printer.
- Image on the print smaller than the projector frame due to an uncorrected shrunken negative printed by contact.
- Combined sound and picture duplicate negatives made with different length negative and track due to lost frames.
- The removal or insertion of sections of material that do not belong to the original text.

... and so on.

Especially in the 1950s and 1960s archives were very worried about how to approach silent cinema, afraid of offering old-fashioned material to the public. Often restorers acted on this concern and attempted to bring the material up-to-date by modifying the intertitles and eliminating some of the scenes. For this reason working on material that has been already duplicated can mean making the extra effort to try to eliminate what can be considered as later interventions that have nothing to do with the original. Some of these changes to programme material are, of course, themselves interesting as reflecting the attitude of the times to both film and to the rest of society, so the final reproductions that were created are worth keeping if they were as finished prints. A new restoration can be prepared based on the new approach, as a separate entity.

The concern of the restorer for the tastes and preferences of the day is quite clearly a mistake if the objective is to reconstruct the original text and visual appearance.

An allied problem that can be seen in many newsreels of the period from 1930 to about 1960, was that of old silent library footage intercut with modern material without stretch printing to convert from 16 fps silent rate to 24 fps sound rate for modern projectors. This jerky, speeded up action seen on the screen was genuinely believed, by a large proportion of the general public, at that time to be what the cinema had looked like prior to 1930!

Television companies showing old news footage in the 1960s changed the public's conception by showing this film at its original speed. This was partly made possible by operating telecine machines transferring film to transmitted signals at 16 fps, and partly by the television companies paying for expensive stretch printing which prints every other 16 fps frame twice to a produce a visually acceptable result when shown at 24 fps. Even as late as 1965 there were very few laboratories in London, for example, which could stretch print. Today no 16 fps film can be shown at 24 fps without the public noticing.

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Part 3

IMAGE AND SOUND RESTORATION

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11

Film damage, repair and preparation

11.1 INTRODUCTION

This chapter includes the identification and treatment of physical damage to films, and the preparation of films for printing and duplication. This work is mostly done in the laboratory, usually by the **assembler** or **negative handler**. This person establishes the physical condition of a film and does what is needed to prepare it for printing: repair, cleaning and other treatments, and provides instructions to other technicians about the proper handling of the film. Identification of physical damage also takes place in archives to monitor the quality of the holdings, and plays a role in the selection of materials for restoration.

11.2 PREVENTION OF FILM DAMAGE

Apart from the deterioration of film bases over time, all films are sensitive to influences from the environment and defects introduced by use. Projectors and viewing equipment may cause scratches, emulsion is affected by fungi, and moisture, dirt, dust and fingerprints are all possible dangers to the preservation of the image over time.

However, most of these problems can be prevented by proper handling, and when treated with care the same film can be printed many times. Although there are various treatments that can counteract present defects of films, one of the main responsibilities of an archive or laboratory is to create working conditions that prevent film damage.

11.2.1 Hygiene

A film handling area should be clean. Particles of dirt and dust may attach themselves to the surface of the films and show in projection. They also may contribute to the decay of the film over time.

The ideal film handling area is a fully air-conditioned room. In this so-called clean area the incoming air is filtered, temperature and humidity are controlled, and there is a positive pressure. This pressure is achieved by extracting from the room a lower air volume than is provided, which creates a higher pressure in the area than in the adjacent rooms. No dust can enter from outside against this constant draught. Clean areas are designed by specialized clean air engineers and are operated with special care – no open windows, special cleaning equipment – to be really effective.

As clean areas are expensive, many laboratories and archives will have to do without full air conditioning. This means that film handling areas need regular dusting, vacuum cleaning and washing. Worktables and equipment should be wiped regularly, preferably with lint free cloths. Eating, smoking and pets should not be allowed in working rooms, to avoid dust and damage to films.

11.2.2 Gloves

The basic rule in film handling is to hold the films only by the edges. As the skin leaves marks that may cause damage it is good practice to avoid touching the picture area. The wearing of gloves is helpful to prevent fingerprints and to spare your hands. Cotton gloves recommended for use on films, as rubber or plastic gloves are easily cut by the edge of the film and give perspiration problems.

For some jobs it is preferable to use bare hands. The repair of perforations is a precision job that requires the use of the fingertips.

When winding old or damaged films, one may encounter splices with protruding corners. In these circumstances cotton gloves are a greater risk, as the film may catch them. When working with bare hands it is essential to hold the film only by the edges.

11.2.3 Cinematographic equipment

Films are easily damaged in winding, viewing, printing and projection equipment. The incorrect use or installation of machinery can do serious damage to film. Especially for archival films, the equipment should be carefully chosen and sometimes adapted for the purpose. Equipment should be installed and maintained by skilled technicians, and operators properly trained. Others should not be allowed to work on it without supervision. The following are some common points of attention.

Winders
Wherever possible it is recommended to use horizontal or flat bed winders that are less likely to cause problems and produce a more even wind than vertical winders, although in the USA vertical winders have their advocates. If a pair of vertical winders is mounted so that the film does not pass straight from one to the other, the film edges can be scuffed or chafed. This can cause scratches, or worse. Powered winders are a greater risk. Old or damaged films are not necessarily wound only on hand winders, but always with attention and a low speed, that allows a quick stop if a splice parts or the film breaks.

Sprockets
When working with archival films the sprocket rollers on any piece of apparatus should be regularly monitored, to see if they can handle the shrinkage of the film. If a shrunken film is forced around a sprocket, the teeth can foul the perforation and cause distortion or tears. When new films are transported by worn sprockets – which can safely handle films with a certain amount of shrinkage – the teeth can catch and tear the perforations.

Footage counters and synchronizers
The film should always pass in a straight path from the feed side to the take-up side without sideways travelling or misalignment. When the film is pushed sideways the film may roll off the sprocket with the risk of teeth digging into the picture area.

Spools
Always use spools and winding plates which are flat, level and run true. If bent, they can easily touch the film surface and cause abrasion, or aggravate existing damage.

11.3 PHYSICAL DEFECTS AND THEIR TREATMENTS

For the examination of the physical condition of a film one needs a ×10 hand lens and a flat bed winder with a light box. This equipment is widely used by assemblers in film laboratories and permits a view of both emulsion and the back (often called the cell, a corruption of Celluloid, side) of the film. The reflected light of the light box gives a good view of scratches and surface defects. In archives a viewer is often used, as archivists are usually more interested in the picture.

To check the quality of prints in laboratories microscopes are also used, with ×10 to ×60 zoom lenses and fibre optic light sources. This equipment is not necessary for old archive films but can be helpful for the examination of high quality films, like new duplicates. For the judgement of physical defects one needs a trained eye and experience. This is not only simply a technical job, it is also an ‘archaeology of the print’ that may help the observer to reconstruct its history, by closely reading the marks that time and different users have left on it.

11.3.1 Shrinkage

Film shrinks by loss of water, solvent and plasticizer. Water is present in both the base and emulsion. The solvent, added to the film base during manufacturing, subsequently evaporates in time. Similarly the plasticizer, which is added to make the film base more flexible, is also lost. Shrinkage occurs to both nitrate base and acetate bases, but nitrate and diacetate shrink more, and more quickly, than triacetate bases. In general the shrinkage happens equally to both emulsion and film base. When this is not the case the shrinkage can cause serious damage to the image: the emulsion may suffer from creases or fragmentation, seen under a lens as a crazing or reticulated pattern.

Shrinkage is related to the combination of the stock characteristics and the storage conditions of the film over time. When stored in a hot and dry environment film loses moisture much quicker than in a cool and humid atmosphere. Films of the same age may have different degrees of shrinkage.

Usually all the reels of a film are more or less uniformly shrunken. In some cases the shrinkage is irregular, due to compilation of different materials or nitrate decay. Leaders and intertitles are well known to show a different shrinkage than the rest of a film.

This degree of shrinkage is an important fact in planning a film restoration. When a film is duplicated, the shrinkage will determine which printer can handle it. Printers are usually designed to transport unshrunken film, and must be modified to have shorter or adjustable distances between the sprockets teeth, or by shorter or variable frame pull down distances. The degree of shrinkage that can be handled by a particular printer depends on the printer design and its modifications.

Shrinkage meters

The degree of shrinkage can be measured in several ways. By comparing a film with a length of new film it is possible to judge the approximate shrinkage without equipment. A simple method is to compare 100 frames of the old film with 100 frames of a brand new film. The shortage in frames of the measured film roughly equals its percentage of shrinkage.

Simple shrinkage meters or pitch gauges are portable bars with two pins to locate the perforations of the film and marks which show its percentage of shrinkage. These are relatively inaccurate. Several accurate pitch gauges are on the market. One is the so-called Maurer type shrinkage meter. This instrument consists of a channel to put the film in, with a lid to keep it straight. One perforation of the film is placed on a fixed pin on the end. At the other end is a movable pin that is attached to a light spring and a dial gauge via a pantograph. This pin is fitted to the 100th perforation – or to any other standard position – numbered from the fixed pin. The dial gauge indicates the shrinkage of the film. A standard rule is used to calibrate the zero position. Modern electronic pitch guages measure shrinkage by guiding it over a sprocket. The percentage of shrinkage is measured over 1 foot and directly given on a display. When the degree of shrinkage changes during the film, it can be readed directly. This kind of equipment is calibrated with dimensionally stable polyester film strips. Shrinkage is measured in %. Most film equipment will handle film that is slightly shrunk, to about 0.4%. However some nitrate film may be shrunk by 2.5% yet be in otherwise excellent condition.

De-shrinking

If a shrunken roll of film is placed in an enclosed atmosphere of acetone, glycerol and water it will slowly expand. When it is kept there for some days (or weeks, at low temperatures) it will re-extend and approach its original dimensions. De-shrinking can be very efficient in enabling shrunken film to be printed on an unmodified printer. As the effect is not permanent, the film has to be printed immediately. The de-shrinking process can be accelerated by using a reduced pressure chamber to increase the vapour concentration in the atmosphere surrounding the film, and temperature is critical. Out of the de-shrinking atmosphere the film will shrink back, sometimes quickly, to approximately its former condition.

Some laboratories have devised their own equipment for de-shrinking. A basic set-up consists of a closed tank in which the film is placed on a grid, above the solution of acetone, glycerol and water (1:1:3 by volume). The film should be brought in loosely wound, and with the emulsion out. There are also commercial systems available, for example, Redimension. In this system the film is placed over an open tray of solvents and plasticizers in a closed metal container, or in a reduced pressure container in a warm place.

Since the introduction of printers that can handle severely shrunken films as a routine – like the Debrie TAI and the BHP Modular – there is less need for de-shrinking processes. For most laboratories it is not a routine job, also because it takes up much time and space.

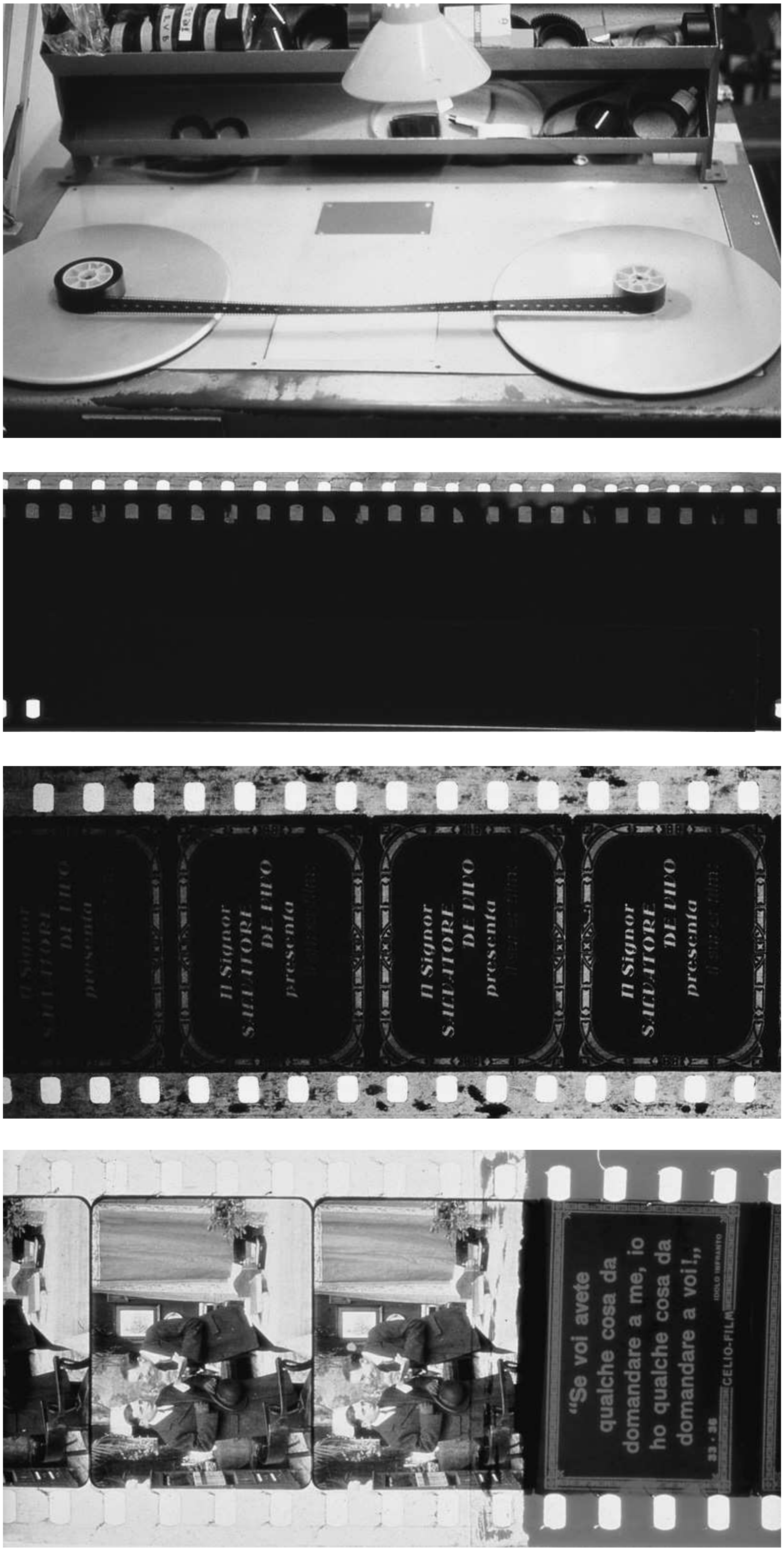


Figure 11.1 (*a*) Flat bed rewind table with an illuminated panel. (*b*) Film shrinkage, one film is modern unshrunk film. (*c*) Very dirty film. (*d*) An original film join or splice

(*a*)

(*b*)

(*c*)

(*d*)

Details of these processes and of the range of shrinkages some typical printers can handle are given in Part 4.

11.3.2 Brittleness

Shrinkage and brittleness are clearly related problems. Due to a loss of moisture and plasticizer the film base or emulsion gets brittle, and can easily sustain damage in handling. Early tinted and toned films in particular are known to have a very brittle emulsion. The technical manuals of the period advised against the use of certain dyes, that seemed to be the cause of this problem.

Brittleness can temporarily be reduced by re-humidification, especially if emulsion shrinkage is the main reason. This can be done by placing the film roll in a closed, humid atmosphere, simply by placing a wet sheet of blotting paper into a can. The film should be kept out of direct contact with the water by lying it on a close wire mesh above the paper. The can lid is kept closed. The film should be rewound daily and the blotting paper re-wetted. After several days the film will have regained some suppleness. The procedure should not be pursued for too long, as the emulsion can become sticky, introducing other handling problems. This treatment is not suited for decaying nitrate film, which is already sticky. The film should be duplicated directly after re-humidification, as it will start loosing moisture again and may shrink back to its former condition within days.

A commercial rehumidification process is Rehumid, similar to the Redimension process for de-shrinking. This system uses a mixture of water and solvents instead of just water, and does allow the process to continue without excessive softening of the emulsion. As with de-shrinking processes treatments to reduce brittleness are not frequently used in laboratories nowadays. The use of solvents and other chemicals may reduce the life of a film. Most of these techniques have never been evaluated from this point of view.

11.3.3 Buckle

Buckle is a condition in which it is impossible for the film to lie flat. If the edges are shrunken more than the middle, the film will take up the shape of an arch, and if the middle is shrunken more than the edges, the result is known as edgewave. Storage of a film in very dry conditions can cause arching, as the outside of the reel will lose moisture more quickly than the inside. Edgewave is usually caused by projectors, which heat the picture area more than the margins of the film. It can also be caused by bad polishing treatments, carried out on the picture area to reduce scratches.

If a film is buckled it is difficult to duplicate it on a contact printer. It will not stay in perfect contact with the print stock, which may result in blurred parts of the image. In some cases these film can be duplicated best on a flat gate step printer, such as the Debrie Matipo, in others a rotary gate (Bell and Howell Model C or BHP Modular) is better. Experimentation is essential.

11.3.4 Scratches

It is widely accepted that an old film is characterized by its scratches. There is an academic school of thought that considers these scratches as a part of the cinematographic inheritance. As it is known that early films were shown to the audience this way, the defects are seen as the authentic 'patina' of earlier times. However, others see the scratches as meaningless and annoying defects, that should be eliminated. Modern duplicating techniques – like wet gate printing – can be very helpful to achieve this.

Early prints are often scratched as a result of working conditions in laboratories and cinemas. Until the late 1920s most prints were directly made from the camera negative, not from duplicate negatives. When the original negative was scratched, the scratch was printed into every subsequent print. The tolerance to scratches is different to today. Whereas they were considered normal, so that technicians and operators were less inclined to avoid them, nowadays laboratories are very clean, and wet gate printing has become almost a standard. This means that scratches can be avoided successfully and old films are usually treated to remove as many scratches as possible.

There is an entire vocabulary to describe different types of scratches. Intermittent diagonal scratches are known as rain, continuous parallel scratches as tramlines, short fine cross scratches are called cinch marks, and so on.

Some scratches can be removed or filled, others cannot. The first thing to realize is that a scratch can only be treated when it is an actual surface defect. Printed in scratches, for example where the original scratched negative is missing, and only a print exists, cannot be removed by any photographic technique. Only digital restoration can be used to produce a scratch free image. These printed scratches will appear as white on the print, as they were black in the negative, or black on the print if they were on a previous print or master positive. Scratches on film always appear on the screen as black, and in colour prints may also be seen as coloured lines.

The degree to which a scratch can be treated and the method depends on the side of the film which suffers the defect: the film base (or cell) or the emulsion. Scratches on the base, also known as backing or cell scratches, are more easily treated than emulsion scratches. Fortunately, the most scratches are usually on the base. Although this side is harder than the emulsion, it is more vulnerable as it comes more into contact with hard surfaces, such as aperture plates and sprocket drive rollers.

Scratches on the emulsion are more difficult to remove. When they are shallow and only affect the top layer of gelatine they can be repaired, but deeper scratches can badly injure the emulsion and result in loss of photographic image. Films that have emulsion layers on both sides of the base – as used in early two-colour systems – are prone to these scratches.

11.3.5 Film base scratch treatments

The appearance of a scratch on the film base can be eliminated on prints and duplicates by wet gate printing. During the duplication the scratches may be filled with a liquid, of the same or similar refractive index as the film base, so that they become invisible. A detailed description of this method can be found in Chapter 13. This is by far the most effective method of scratch removal.

Two older methods exist for the actual treatment of scratched film, varnishing and polishing. These are less and less used nowadays, but treated prints can be found in almost every collection. Varnishing or lacquering consists of the filling of scratches in the base with a varnish. In polishing the original production method for film base is used: the film base is softened and pressed against a flat surface, so that the scratches are filled with base material. All scratch treatments of this sort, especially polishing, should be used only as a last resort. Once treated, the effect, good or bad, successful or unsuccessful, is permanent.

Varnishes and lacquers

The material used to fill in the scratches should have the same refractive index as the film base. Wood varnishes, copal or yacht varnishes were used because they were flexible and strong. The varnish was applied in many ways: by brushes, rollers, sponges and total immersion. Sometimes it was applied on both film base and emulsion. These processes were used on scratched prints and also on new release prints, before distribution. Any scratches that occurred then might be restricted to the lacquer. The damaged lacquer could be removed with a solvent, and relacquered again. Negatives were rarely varnished as the process reduces the print quality. Nowadays varnishing is not recommended as a method for scratch removal. Future removal of the lacquer can be difficult, and there is reasonable certainty that the treatment has a negative effect on the stability of the film.

Removal of lacquers

Sometimes it will be necessary to remove a lacquer, e.g. when it is discoloured or damaged. As it was applied to a scratched film it can be expected that the film beneath the layer is also damaged and needs further attention. Old lacquers need to be tested to find the right solution for removal. Usually a 1,1,1-trichloroethane or perchloethylene solution is tested first. This is done in a solvent cleaning bath. If it does not works, other solvents are tried, like methanol, carbon tetrachloride and cellulose thinners. As these solvents are very toxic this work can be carried out best by a specialized laboratory, and certainly with specialized air extraction.

3M Photoguard

Photoguard from 3M is a liquid polymer coating cross-linked by ultraviolet irradiation.

It was used after 1975 on release prints and duplicate negatives, and is much tougher than old lacquers and varnish. Photoguard can be removed only by specialized techniques operated by the manufacturer's franchise. If it is considered necessary to remove these coatings the manufacturer or their local franchise has to be contacted. In some case removal may not be possible and the coating must then be considered as a permanent feature of this film.

Polishing

During the polishing the base is softened with a solvent and pressed onto a surface against which the film base hardens. The scratches will be filled in with the softened substrate, and is invisible once the new base surface has been formed. Both acetate and rotating glass wheels have been used as the new surface. This surface should be flat, smooth, polished and blemish free. As the process operates with a contact time of only 4–6 seconds, a large 35 cm diameter wheel can polish about 20 m per minute.

A first pass using a matting wheel can treat serious scratches. This wheel had a finely ground sanded surface that creates a matt film surface. Intertitles and high contrast images were sometimes left in this stage. Print and negative images were then given a second treatment with the polished glass wheel. This method filled in even gross scratches, although some overall definition was lost. If the job was done badly, or dust allowed to be incorporated the results could be worse than the untreated film.

Over the years there have been many manufacturers of polishers – Arri in Germany, Carter in the USA, and several patented systems, like the Davies and Doel-system in England. Since the late 1980s is it less and less done, as wet gate printing is more effective. However, when the equipment is still available an archive or laboratory should keep it, for the treatment of small sections or laboratory 'accidents'.

11.3.6 Re-washing

Re-washing can treat scratches on the emulsion side of a film. This is successful only when the damage is rather superficial. The emulsion of the film is immersed in water, allowing the gelatine to soften and swell. The edges of the scratch will anneal and as the film dries they will stay together. Deep scratches can only be slightly improved, and if any emulsion is lost the effect may be negligible. Nevertheless, the effect of re-washing on smaller scratches can be very good. Only the top layer of the film should be wet, so the wetting time is usually kept as short as possible, and special solutions can be used to swell the top emulsion layer.

Several manufacturers made special machines and solutions for re-washing, and in some laboratories equipment is used that re-washes and cleans the films in one single operation. Kodak has a re-washing process called RW1, and many laboratories use a process solution from the ECN2 process, the Prebath, for re-washing. A formula for a re-washing solution that softens emulsions rapidly and evenly is given in Part 4. After the re-wash solution there should be a water wash, as used in normal processing. Any of these processes is suited for black and white archive films.

11.3.7 Drying marks

Drying marks are the result of uneven drying of the emulsion during processing. Droplets of hard water that evaporated from the emulsion surface have left a raised 'shore line' often with fine particles stuck to the emulsion. When soft or distilled water is used during processing there are virtually none of such marks. Some archive films show very old drying marks, dating from their original process up to 80 years ago. Usually they look like a trail of droplets or a continuous tide mark down the length of the film. All drying marks, even when very old, can almost entirely be removed or at least reduced by re-washing the film. Just as with scratches, the removal of these marks can be a source of argument, as they may have been there from the very first showing of the print.

11.3.8 Dirt

Dust, stuck on dirt and fingerprints contain chemicals or fungus spores that may cause harm to a film over longer periods of time.

Pollution with oil or grease will make it slippery, and more attractive to dust particles. Especially early release prints suffer from oil, which leaked from unproperly maintained projectors. All dirt and oil that is not caked to the emulsion can be removed by film cleaning methods, as described in the last part of this chapter. When dirty films come into an archive they should be cleaned before long-term storage. Greasy projection prints should be cleaned as well, as the slippery surface may cause handling problems. In general clean working conditions help to reduce a build-up of dust and dirt, and fingerprints can be avoided by touching the film by the edges.

Process dirt is the name of small particles that stick to the emulsion. It is a physical defect that arises during the processing of the film. When the processing solutions are polluted with dust and fine gelatine particles these may pick up on the emulsion surface. Process dirt can be removed successfully by re-washing the film. The defect is usually found on older films, as modern processors eliminate the problem by using continuous filtration systems that keep the processing solutions clean.

11.3.9 Ferrotyping

Ferrotyping is synonymous to 'glazing', a method to give photographic papers a shiny surface by drying the emulsion on a hot steel surface. In cinematography 'ferrotyping' is a term to describe glossy marks on emulsions. These changes in the normal matt appearance of the emulsion are caused by a combination of tight winding and humid storage. The damp lets the emulsion swell and when it is pressed against the adjacent convolution it takes on its smoothness and glossiness. The effect is often local, in irregular, patchy shapes.

Ferrotyping is not serious in itself, as the photographic image is unchanged. Sometimes the ferrotyped areas have sharply edged boundaries which show on the image as dark wavy lines. As these lines might be visible on a next generation of film they should be removed before duplication. Some ferrotyping is easily removed by a water wash. To quicken and intensify the treatment a solution can be used that swells the gelatine. For this purpose a re-washing solution, used for emulsion scratch removal, can be helpful.

11.3.10 Damage to perforations

Nowadays film equipment is more and more designed to treat the film gently. Printers and telecine equipment often transport the film without sprockets, drives and other parts that may cause perforation damage. But this is a recent development: in the past the strain on the perforations was a constant in every film transport system. As perforations are vulnerable, damage to perforations is a problem every archive and laboratory will have to deal with. To avoid further damage, especially shrunken films should be watched closely during handling on synchronizers and viewers.

When stressed, the edges of the perforations burr. As the tension increases, they may bend, distort and ultimately tear. Burrs and minor damage may cause the film to be transported unsteadily and the image to jump. Small tears, also known as **split perforations** or **crowsfeet**, usually have little effect on the image steadiness. These tears may be quite slight, just a millimetre along the length of the film from the corner of the leading edge. As they make film weaker they can result in more serious damage in the future, like completely torn perforations, a tear going from the perforation to the film edge. More drastic damage to the perforation may occurs when a film runs out of sprockets, or entire sections of perforations are pulled through.

11.3.11 Repair of perforations

The practice of film repair is one of intervention and it is generally held that it should be restricted to only what is necessary. As cinematographic equipment has different capabilities in handling damaged films what is necessary depends on the required use for the film. Torn perforations in a print that is to be projected or shown on viewing equipment need more repair than a film that is to run on a telecine. Repair should be done immediately before the actual use of the film. It is not recommended to repair films before long-term storage, as repair materials like adhesive tape may deteriorate and affect the film over longer periods of time. Repair of damaged perforation is often done in one session with a complete check of the physical condition of a film, at the same time as the renovation of splices.

If a film is repaired for duplication the work will depend on the printer to be used. Some modern equipment is suited to handle seriously damaged films. Printers like the Debrie TAI need only good perforations on one side to transport a film steadily. Sigma and BHP Modular printers and Cintel and Philips Spirit telecines can even handle short lengths of film without any perforations. The necessary repair for this kind of equipment consists of the cutting off protruding edges of the torn perforations. Missing perforations may not need to be restored, saving hours of work.

Repair by adhesive tape

The easiest and quickest way to repair damaged perforations is by special perforated adhesive tape, e.g. Perfix. This is available in rolls for 35 and 16 mm film and covers the perforations and outside margins of the film. Usually the tape is designed to use with special equipment that applies it automatically along the film, but it can also be used manually. When repairing with adhesive tape it is essential to cut away distorted or torn edges to allow the tape to lie flat. Especially on shrunken film it is better applied by hand in pieces of more or less a frame length. As the equipment can usually handle the stiffness of the extra layer, it is advisable to stick the tape to both sides of the film to hold down projecting edges.

Another method is to use normal adhesive splicing tape. The tape is applied across a damaged section, overlaying the margin of the film on both sides. As the tape sticks to itself it creates the missing film area. A tape splicer is used to punch the perforations into the splicing tape. This splicer should be well maintained, and have sharp perforation cutters. Any tape covering the image, or sticking out from the sides can be cut away by hand. This method can be rather effective for the repair of lost perforations. A disadvantage is that the adhesive splicing tape can be distorted after printing, and should be removed to avoid the spreading of adhesive on the archival print.

Repair by cement

Sections of missing perforation can also be restored from another film. This method is particularly useful for badly shrunken films. A piece of scrap film is taken with the same degree of shrinkage as the damaged film. From this piece a run of perforations is cut that overlaps the missing area by two perforations. It is cemented base to base on the healthy perforations at both ends of the damaged section, one perforation overlapping at each end (for cement splices and formulas, see the section on splices). This method is very elegant, as the repaired section is comparable to the original material, and the results have good archival permanence. A disadvantage is the increased thickness of the cemented edges, that may cause problems in some printers. Old style flatbed printers can often cope with this; for other printers sometimes extra adhesive tape is applied over these areas. Some printers cannot handle the increased thickness at all.

11.3.12 Tears

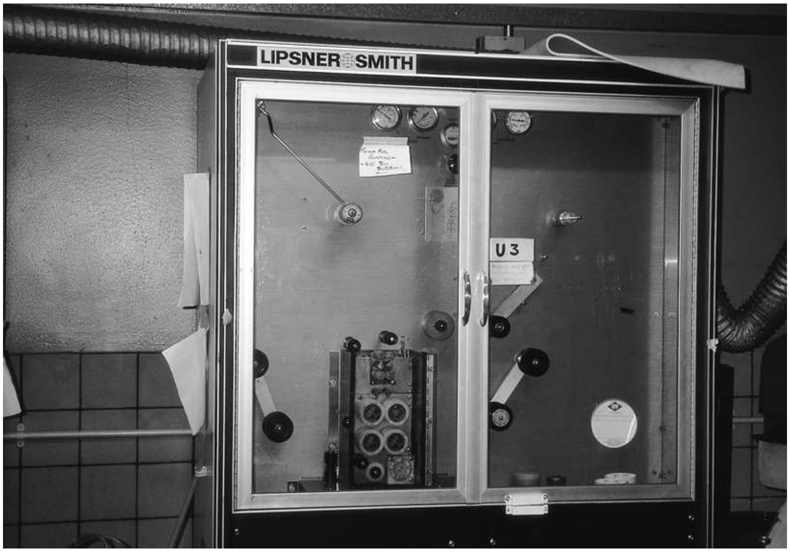
Repair

All tears are repairable, provided that no pieces of film are missing. However, a repaired tear will be visible in the image and reduce the quality of the print.

The first stage is to bring together the torn edges. The edges of tears are almost always jagged, so the work of fitting them together is delicate. It must be done carefully, trying not to leave any space between the edges that would show as white lines in projection, black lines after printing. Fundamental to the repair is to maintain the original film dimensions and perforation positions. A helpful method to achieve this is to use masking tape or double-sided tape to fix the film to a light table and assemble the pieces on the tape. It is recommended to remove dirt and grease from the pieces, by using a cleaning solution on a lint free cloth.

When the pieces are positioned they can be stuck together with adhesive tape. This is applied to both sides of the film, preferably in a tape joiner. Avoid air bubbles under the tape as they would be visible in the image. When perforated tape is used there should be a good match with the perforations of the film. If this

Figure 11.2 (*a*) A Lipsner–Smith ultrasonic solvent film cleaner. (*b*) Inspecting film at Soho Images in London. (*c*) Film damage, perforations missing completely on one side. (*d*) Repairing damaged perforations with perforated tape at L'Immagine Ritrovata, Bologna. (*e*) Replaced damaged perforations. (*f*) Torn film can only be repaired by transparent tape



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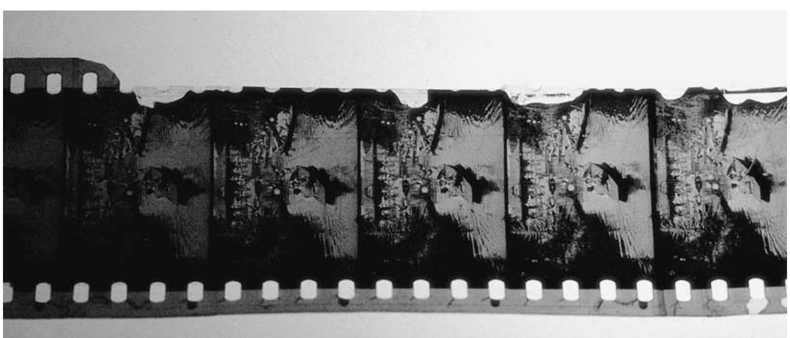

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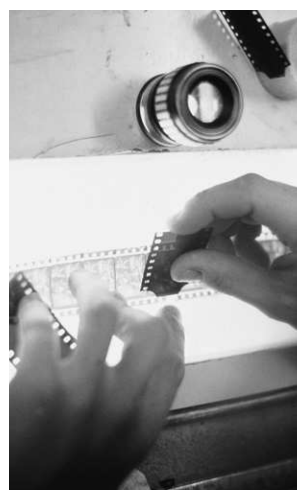

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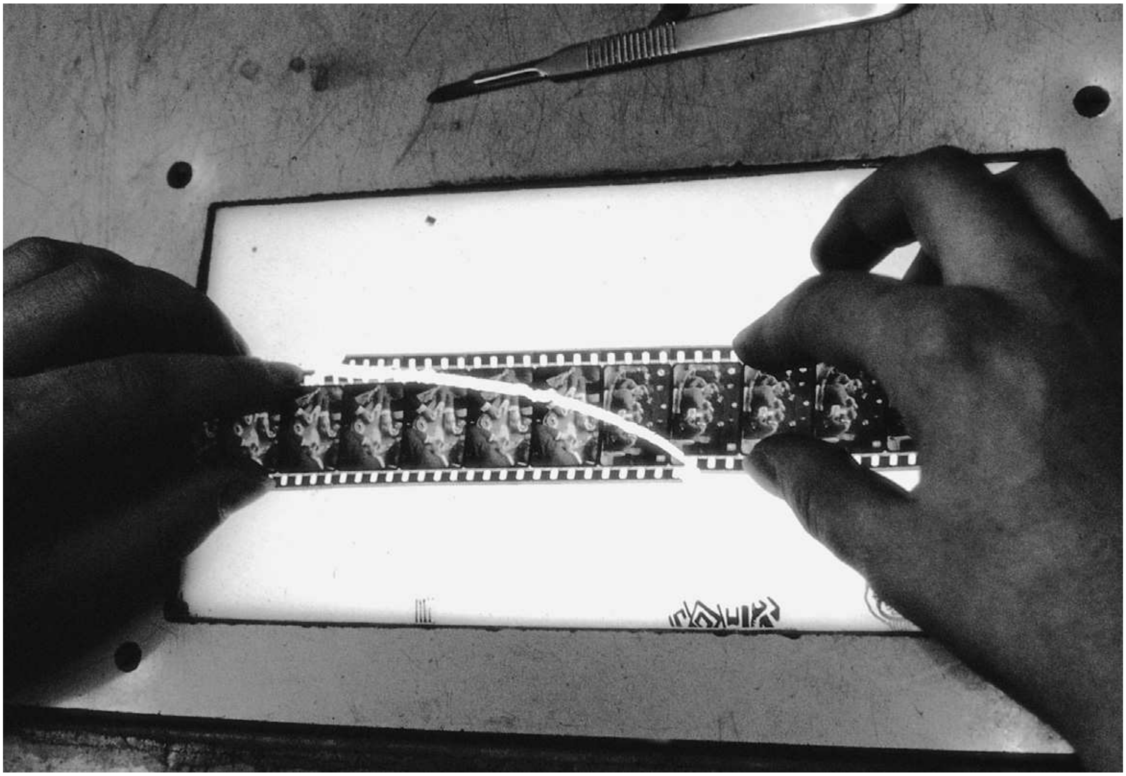


(*f*)

procedure is hindered by shrinkage, it is possible to apply the perforated tape in short sections of one frame at a time. Another solution is to cover the image area with broad splicing tape, and leave the perforations free. When the repaired film is duplicated it might have difficulties with some printers. Some modern equipment, like rotary contact printers, is not very tolerant to the two extra layers of tape, which make the film stiffer than normal.

Blooping

When a torn film is repaired it is sometimes unavoidable that a piece of image is missing. In projection this gap shows up as white. To reduce its visual impact the area can be blacked out with **blooping ink**. This is a dense, optically opaque ink developed to cover clear areas in sound film. Blacked out areas attract considerably less attention on the screen than white areas. Blooping is only useful for positive films: for negatives it is better to leave the missing areas clear, so that the printed image is black.

Blooping is indispensable to remove clicks and damaged areas that produce extraneous sounds from optical sound tracks. A splice in a soundtrack produces a click, a disturbing sharp noise, since a small clear area is left between the edges of the two films. Blooping ink removes these clicks by covering the clear area with ink. This should be done only when the volume of the sound is low. When there is loud noise or music the click will be less noticeable than a gap in the sound, so it is preferable to leave it there. Blooping ink can be removed with most cleaning solvents if the effect is too obvious. There are also preformed stencil shapes and self-adhesive peel-off patches of dense material on the market to help with this process. However, blooping ink has more permanence and is equally easy to apply, but may be removed by solvent film cleaning.

11.3.13 Splices

Splices join sequences of film. These can be made with glue – so-called cement splices – or with adhesive tape – tape splices. Silent prints have many cement splices, as usually the cutting was done on the positive. These splices occur most frequently at the insertion of intertitles and at the colour changes of film sequences, although most uncoloured films were positive cut too. The transition to negative cutting coincided more or less with the introduction of optical sound. Sound film prints usually have few splices, and where they occur these may create disturbing noises in the prints. Cement splices in a 35 mm print are less disturbing than in a 16 mm film print. In a 16 mm print the overlapping parts of the splice in the negative extend into the adjacent picture area, and appear as a light bar in the first and last frame of every cut. To avoid this 16 mm negatives are often cut in A and B rolls, although this was not common until the 1940s.

Cement splices

Cement splices use a solvent glue to dissolve the film base and fuse the two superimposed pieces together. Since the emulsion cannot stick to the film base the emulsion in the cemented area is scraped off. The thickness and the width of the splices can vary. Early joins are often very thick, as there has been little scraping, and the overlap is usually broader than in recent splices, up to a third of the picture area. Usually smaller splices are used for negatives, and broader and stronger ones for positive films. Normally the joins are made in the frame line area. Until quite recently almost a full frame was lost to make the overlapping area for the join, but with modern splicing techniques this can be avoided.

Splices are not only used for the joining scenes of prints and negatives, but also for repair. Cement splices that are found in the middle of scenes, and splices in sound films are almost always made by operators after a break of the film during projection. In this case a jump cut will be seen since one or more frames were taken out to make the join. Over time the cement joins tend to weaken and some may completely fail: the join is then said to 'dry'. This deterioration depends on the film base, the quality of the join, and the solvent mixture used. Joins made in the 1930s are more likely to dry than later ones, since chemical additives that improved the life of the joins became available in the 1940s. The solvent, so-called film cement, is almost always a solution of acetone and other chemicals.

Cement splicers

The standard cement splices are, and were, made with small portable splicers, available in different designs for negative and positive films. A negative splicer produces narrower joins than a positive splicer. Usually the splicer has a small device for the scraping of the emulsion, otherwise this can be done by hand with a file, a sharp knife or a scissors blade. The scraped film sides are held on pins, the film cement is applied to one of the joining sections, and the splicer is closed to join the two pieces with some pressure. In a few seconds the cement is hardened and the splice is ready.

Cement splicing requires practice. The amount of cement is critical: too little cement results in separating edges and too much takes longer to dry and the risk of squeezing cement into the picture area. When starting to make cement splices it is recommended to practise on pieces of scrap film. To test a splice the film should be twisted: if it parts the pieces are not adequately joined. These standard cement splices involve the loss of at least one frame of the film.

In many laboratories large foot pedal operated joiners were used. Some were fitted with heated plates to speed up the drying process. These are rare today.

A Hamman splicer creates a very narrow splice, that fits within the frameline of a 35 mm film. The cut and overlap area is diagonal and made within the thickness of the base, so that no scraping is required. A Hamman join can be nearly invisible and as strong as a standard cement splice. These joins are widely used for modern negative cutting, as they pass through the printer smoothly, resulting in a steadier picture. Hamman splicers are also available in wider design, useful for positive films. Like standard cement splices the making of a good Hamman join requires a lot of practice. As the overlapping area is entirely in the film base, no frame need be lost using this splicing technique.

Film cements

Current commercially available film cements are designed for acetate film, and widely used in archives and laboratories. These cements can also be used for nitrate films, but are less effective than some special formulas. Formulae for acetate and nitrate based films, and for joining acetate to nitrate film are to be found in Part 4. Harold Brown, a former member of the FIAF Preservation Commission, has collected these recipes.

As film bases comprise slightly different compounds the effect of a film cement can sometimes be unpredictable. When a cement does not work well on a particular base, try another one. To make the solution somewhat more viscous one can dissolve some of the film base in the cement. When everything fails to join a particular film – this happens on rare occasions – a special solution can be made. This formulation dissolves the film base and, in effect, welds the two pieces together with the dissolved base material. This formula can also be found in Part 4.

Tape joins

Splicers that use adhesive tape instead of film cement were not extensively used before the 1960s, when this tape became a common product. Tape splices are quick and easy to produce. The ends of the film are cut off on the frameline and pinned on the tape splicer without overlap. The tape is pulled over the join by hand, and rubbed to remove remaining air. This is done on both sides of the film. The splicer cuts off the tape and punches the perforations open. Tape joins are easily applied and removed, without damage or risk to the adjacent frames. Another benefit is that they can be made without loss of frames. Tape splices are mainly used for positive films, as tape splices on negatives show on printing. Amateur 8 mm film formats always have tape joins.

A disadvantage of tape splices is their lack of permanence. Nowadays adhesive tape is made of durable polyester, but the bond between polyester, glue and film will inevitably loosen in time. In older films adhesive softens and oozes out from the splice. Sometimes the splices stick to adjacent layers of film with a serious risk of causing damage to the film when rewinding. When they show signs of deterioration, tape slices should be removed and the remaining adhesive wiped off with a solvent. Softening tape splices seem not to affect the image, but it is accepted they have a negative effect on both nitrate and acetate decay. It is recommended to use professional splicing tape, that will not discolour and will put up with being wet, to some extent.

Fusion joins

Special joining methods have been developed for the joining of polyester film, for which there is no solvent available that can act as a film cement. There are different systems available, so-called hot-weld or ultrasonic splicers, that join the pieces of film by heating and melting them. Other systems work with tape that is bonded to the base by heat. All negative cutting of polyester base films is done with fusion joins; for positives, tape splices are also used. As ultrasonic and hot-weld splicers are not able to join polyester to acetate film, these splices should be made by tape. Some joiners join the film ends together in a flat weld at the frame line, sometimes called a butt join.

Repairing splices

Old splices need to be checked before duplication to be sure they will not come apart on the printer. Telecine machines with capstan drives are less critical than printers with sprocket drives, but so much damage can be done by a break on a machine that splices should be examined before every job. This can be done by simply twisting the film. If the splice starts to part, it will be unsafe on the printer. When a join is unsafe it can be remade by cement or tape.

Weak cement splices can often be peeled apart, and the overlaps rescraped and recemented. The overlapping area can be trimmed with scissors, to reduce a broad cement splice to smaller proportions. The re-cementing can be done by hand, or on a cement splicer modified to handle the shrinkage of the film. One should always stick to the original positions of the perforation, whatever the frameline position may be. If the spliced area is damaged, and frames would be lost to make a new one, a tape splice can be made. In this case the remaining overlapping areas of the old cement splice are cut off.

Some repairers reinforce the old cement splices by placing a tape join over the top. This can be done by small 8 mm tape that will show on the duplicate. For tape repairs generally 16 mm and 35 mm adhesive tape are used. On the duplicate of the repaired film this tape will be visible as thin lines, especially in the light areas of the image. When repairing with adhesive tape one should avoid gaps between the spliced ends, as these are a weak structure likely to snap in the printer. Air bubbles and dirt under the tape should also be avoided, as it will be visible on the new duplicate.

Most cement splicers can be modified to handle shrunken film by replacing the pin plate designed for short pitch. Older tape and cement splicers with worn pins will already accept a degree of shrinkage, and pins on new splicers can be filed down on the edges to achieve this. For early films it is recommended to keep an old splicer with removed outer pins. These will be able to handle even the most shrunken materials.

11.3.14 Damage by fungus and bacteria

High humidity and high temperature will promote the growth of fungus and bacteria on the emulsion of films. However, films that are not stored in poor conditions have also been found to be attacked by organisms. Nitrate and acetate films are affected equally. Only some colour films seem less susceptible, because their processing included formaldehyde, a very good fungicide. It has been noticed that tinted films are frequently affected by fungal growth, as some dyes are a good substrate.

The distinctions between fungi and bacteria are imprecise, but it is possible to distinguish between the two under a microscope. The fungal hyphae can be seen as strands, whereas bacterial colonies appear circular or patchy even under a hand lens. At higher magnification bacteria look amorphous as the individual cells are not obviously arranged in chains. The appearance of fungi or bacteria on a film can be very serious. However, some colonies are entirely superficial and can be wiped away or removed by a cleaning solution. Others will have damaged the emulsion so much that it will start to separate from the base.

Strands of fungus growth can gouge troughs in the emulsion surface. This effect is known as **etching**. These troughs are permanent scars in the emulsion surface and may also show on a duplicate of the film. Fungal hyphae can burrow extensively, sometimes forming a network of tunnels below the emulsion surface. Sometimes just one coating layer suffers from this damage.

In many cases the growth of fungus and bacteria will stop without any influence from outside. Probably the conditions that the organism liked have ceased to exist and it is either dormant or dead. In any case it is important to take a close look at the fungus or bacterial growth before treating it. Treatment can be done in the following way:

1. Removing the growths.
2. Minimizing the effects on printing.
3. Preventing further infestation.

Removing growths

Inspect the film under a microscope; use a needle point to probe the image area to check whether the growth is on the surface or below the surface. Gently find out if the emulsion is still firm and in good contact with the base.

If the emulsion is firm the film should be rewashed. This usually removes all the surface growth and cleans out any grooves cut by fungi. If the growth is all on the surface no further action will be needed except to ensure that any possible remains of the organism are dead. There does not appear to be any method of removing hyphal strands from inside the emulsion and they may remain as a fine dried black network.

Minimizing the effects on printing

Wet gate printing has a positive effect on surface damage caused by fungi. When there are tunnels inside the emulsion layer, the damage is more difficult to reduce. One treatment is to fill them with a liquid. Organic liquids, like mineral oils, will penetrate into the tunnels and reduce their appearance. The film has to be stored in the liquid for some days or placed in a vacuum chamber, like those used for the **Vacuumate process**, with the film immersed in oil. The film is then hand cleaned and printed on a contact printer. The visual appearance is quite good but never perfect. After the printing the film should be cleaned to remove the oil. As there is no information on the long-term effect of this treatment it should be regarded as a technique of last resort.

Prevention of further growth

Many biocides are on the market to prevent the growth of algae in process machines, and these are effective in killing fungi and bacteria. These solutions are said to have no effect on the permanence of the film. The oldest is domestic bleach or sodium hypochlorite. This solution is very effective in the prevention of infections but is not persistent when dry. Dearcide, sodium trichlorphenolate or Morpan BC80 (benzalkonium chloride) as 1% solutions in water are also good biocides that kill any hyphae or spores on films with fungus or bacterial damage.

One word of warning regarding the use of special rinse baths for colour materials. Many colour films from 1955 onwards required a last rinse of a formaldehyde solution as a stabilizer and hardener. These films rarely suffer from fungi probably because they have some residual formaldehyde remaining and this is very toxic. If such a film is effected the last rinse should be a solution of 6 ml of 37% formaldehyde in 1 litre water with a drop of Photoflo to simulate the original last process stage. Formaldehyde is a very effective biocide and will protect the film from further growth. If in any doubt this last rinse can be used for all incorporated coupler integral tripack colour films.

Health and safety

Very few fungi cause illness in people but it is possible that allergies could develop in people who are sensitive to high levels of spores. People with a history of lung disorders, people who are taking antibiotics and people wearing contact lenses should avoid working with fungus-infected films.

Everyone handling infected films should wear gloves and a full nose and mouth mask with a fine filter (down to 4 microns). Movement of infected films should be kept to a minimum to avoid spreading spores or infective hyphae, and films should remain in a container until needed.

As all biocides are toxic, the recommendations for handling them must be checked before use and the instructions followed. All rinse baths containing formalin (a solution of the toxic gas formaldehyde gas in water) must have a surface cover or extraction, and the area must be regularly monitored to keep the concentration of formaldehyde down below the recommended TLV.

11.4 WAXING

Prints were often waxed to smooth their transport in the projector and increase their useful life. This process may have started very early. There are many recipes for waxes in early and later literature, generally consisting of dissolved beeswax or paraffin wax in Xylene, later replaced by 1:1:1 trichloroethane. The film was either waxed overall by dipping in the wax solution or over a waxed cloth roller, or, more economically, by application to the edges only. Usually the film was buffed afterwards to polish the applied surfaces and dry the wax. A waxed print is transported through a projector more quietly than an unwaxed print, especially on old projectors.

Old waxed prints are often extremely dirty as old wax picks up dirt easily. The solvents used for film cleaning easily clean off all wax.

11.5 VACUUMATE

Restoration House Inc. of Canada introduced the Vacuumate process more than 30 years ago as an overall treatment to improve the suppleness and lubrication of films and to give some protection from fungi. It has been used especially for cinema prints prior to being sent to the tropics and to treat films that have already been affected by fungi or bacteria.

The process takes place without unwinding the roll and without passing the film through any liquid. The reels are placed in a vacuum chamber and the pressure is reduced to 30 mmHg. The temperature is controlled to 25°C. In a sequence that takes about 2½ hours five separate chemical mixtures are released into the chamber. These vaporize and are taken up by the film emulsion and/or the film base.

11.6 FADING OF BLACK AND WHITE IMAGES

Black and white images are very stable, as the grains of metallic silver are more durable than the film base. However, the most decisive factor in conservation is how effectively the film has been washed. When the salts, used for the fixing of the film, are not completely washed out of the gelatine layer the silver image will fade. This is a result of conversion of the silver to a thiosulphate salt. In some cases this fading may be corrected by bleaching with a ferricyanide colour bleach followed by redevelopment with a black and white developer. This treatment is not always successful, but it can significantly smooth out the blotchiness of faded black and white images. This is a safe procedure – it may not work, but it does not impair the future life of the film.

11.7 DYE FADING

The fading of colour images is a more common problem than the fading of black and white images. Films from the silent era, produced with early colouring methods, may be faded by projector light. Early chromagenic dyes, produced during the development of subtractive colour film, were unstable and frequently lost both yellow and cyan, leaving a magenta image.

There have been many dyes used in colour photography over the past 50 years and their stability to ultraviolet light has improved, to the point when today the dyes can withstand ten times the UV exposure that would destroy the 1935 Kodachrome dyes. Technicolor dyes, for a long period Metanil Yellow, Rhodamine and Patent Blue, are also quite good, but there were periods when poor stability seems to have been a problem.

11.7.1 Causes of dye fading

Storage conditions, particularly high temperatures and humidity.

Irradiation from the projector lamp. The high ultraviolet content of some projection arcs fades dyes, and this can be seen as a faded central spot or area in each frame. This is the most common cause of fading of coloured films from the silent era.

The chemical and physical properties of the emulsion matrix material.

Low formaldehyde concentrations in some colour process stabilizer solutions can shorten the life of some incorporated coupler colour dyes.

11.7.2 Fading of tinted, toned and handcoloured films

Toning is the process of changing the silver image for another image chemical. Some alternative images are much less stable than metallic silver, and most fade to some extent. Iron-tone blue, also called Prussian Blue, fades slowly with ultraviolet light from projectors and it also appears to darken considerably with age. Some of the orange tones, especially uranium ferrocyanide, appear to darken and to change colour to a duller, redder hue. Some toned images have faded unevenly, a problem for which there is no conventional photographic solution.

Sepia toning is the conversion of the silver image to silver sulphide, which has a warmer, browner hue than the neutral grey of silver. Sepia toning also changes over time, but is known to be unaffected by residual fixer salts. The colour becomes more neutral and the colour effect is lost but the density is usually maintained. On the other hand most toning is quite difficult to identify after all these years and not enough is known about some original colours to predict the changes that have occurred.

Tinted film, where the base or the emulsion is coloured overall, is generally more stable than most toning, with some notable exceptions. Heat from projector lamps has the effect sometimes of reducing colour saturation, especially of some reds. In general it seems that yellows and reds were more stable than greens and blues. Some of the old blue dyes fade unevenly in a most characteristic and unpleasant way. Tinting of the base seems to be more stable than the laboratory processed emulsion tinting. Stencilled colours and brushed on colours are generally as stable as tint dyes, as the same dyes were used for both.

11.7.3 Stabilization of dyes

Most chromagenic dyes are stable when maintained at a constant pH of about 5.0–6.0. The final stabilizer, rinse or process bath is usually a buffer, a solution used to provide a stable pH condition in the emulsion. Many dyes are known to be at their most stable if the emulsion has some residual stabilizing chemicals left. Formaldehyde is widely used in the last process stage for some films as it improves the stability of the magenta dye. Eastman Colour Print film and Ektachrome Commercial film required the SA-1 or the ECO stabilizer to maintain magenta dye stability.

The Kodak S-9 stabilizer had a carefully defined pH. SA-1 and ECO stabilizer solutions contained formaldehyde. It now seems likely that a considerable amount of fading of the dyes of this period (1950–85) may be due to faulty processing at the time the film was made. Formaldehyde in the process solutions was rarely analysed or chemically controlled at that time, and the pH of stabilizers was widely disregarded since neither contributed to the visual quality of the film at that time. Only wetting agent concentrations, which helped drying and reduced drying marks, were regularly checked.

A further problem is that cinema release prints were often cleaned using water, especially if needed for a second release, and many laboratories used a simple water wash to anneal fine projector scratches. After this the film should have been re-stabilized, or re-buffered, but rarely was. In consequence these treatments, which wash away the residual chemicals, may have accelerated the process of fading.

Little research has been done to establish whether re-stabilizing these faded colour films now would prevent the fading from continuing, or slow the process. However, several archives have re-stabilized or re-buffered valuable colour film in the hope that this will be of some value. The best that most manufacturers can suggest is that if the original stabilizer or buffer formula can be found re-stabilizing would not hurt. Eastman Kodak's recommendations to use a sulphite bath for cleaning and rewashing did not, and still do not, emphasize enough the need to follow up with the original process stabilizer or buffer solution.

11.8 FILM CLEANING

Film can be cleaned by a number of different methods: by water, by organic solvents or by adhesive surfaces. Cleaning of all film between the various stages of restoration is essential, just as film is routinely cleaned in modern film laboratories between production stages. There are differences between cleaning as carried out by conventional film laboratories on modern film and the cleaning of archive film.

Fresh negative film in modern laboratories is always cleaned between each handling or printing stage using a solvent in an ultrasonically vibrated bath to remove dust, fingerprints and minor dirt particles. The procedure is one of ensuring that nothing is present that could impair the printing process and be seen on the print as 'sparkle', tiny spots of clear film where a speck of dust was stuck to the film, or be a source of abrasion.

Cleaning archive film for the first time can be as simple as this, but archive film is frequently unbelievably dirty; so dirty that it would seem that it had never been cleaned in its life, which may be the case. Projection prints that have been on a cinema circuit could have had almost anything done to them from being covered in spilt coffee to being run onto the projection room floor because the take-up system failed (a very common problem).

Early silent films that have not been touched for many years may have so much applied grime that a cleaning process may remove measurable amounts of material. In one such case a well used 5 min (500 ft) Pathé Pictorial print of 1952 weighed 12 g less after ultrasonic solvent cleaning! The subject of cleaning is complex and the following issues are special to archive film.

11.8.1 Cleaning before repair?

It is usual to inspect film and sometimes to carry out repairs to film before cleaning prior to printing, and in the case of negatives this is the best policy. However, old prints and some old well-used newsreel negatives are so dirty that cleaning may be needed before any work commences to avoid spreading the dirt or the dirt and grime creating additional scratches and abrasions. In any event, all film should be cleaned after repair and immediately before printing.

11.8.2 Selecting the method

There are many ways to clean film. Processes that use rotating buffers are rarely used on old film as they risk damage to insecure splices and torn perforations.

Solvent cleaning is essential for really dirty film. The choice of solvent is restricted today by the Montreal Convention. Water cleaners are effective too but less so than solvents, although water is more effective for detaching particles stuck to the emulsion and in this case the section above on rewashing should be consulted.

Modern particle transfer roller systems are not effective on old archival film, but are very more appropriate for keeping clean modern restorations and for local use on printers and processors.

11.8.3 Essential procedures before cleaning

Testing

The first procedure before any cleaning is carried out is to take a white cloth with a little perchlorethylene on it, the normal solvent used for solvent cleaning, and wipe about 30 cm of the film gently about three times and look at the dirt removed on the cloth. If the dirt is dark and very obvious cleaning must be done in a cleaning system allocated to dirty film and cleaned a second time in a 'clean' machine (unless a 'Clean band solvent cleaner' is used, see below). This is particularly essential on solvent cleaners in laboratories handling new negative film, which will be contaminated by the dirt taken off really dirty archive film. All cleaning machines have filtration but this is not able to remove grease and oils and a 'reclamation' process will be needed to clean up the solvent before it can be used for fresh film. The good practice is to keep a cleaning machine specially for the first clean of archive film.

If the film was tinted and colour is removed onto the cloth, solvent cleaning may cause some dye loss. Unfortunately, if dye is removed no cleaning method may be possible without colour loss and this dilemma may have no solution – the image may be left dirty, or clean and without all the dye! In an informal series of tests at Soho Images in London it was found that dye loss from tinted images in a solvent cleaner was extremely rare, although very serious when it occurred.

Magnetic tracks should be tested for cleaning as some solvents will remove the magnetic coating. A cloth with cleaning fluid should be used on an unimportant part of the film. If a brown colouring appears on the cloth, no further attempt should be made to clean the magnetic track with that solvent.

Lacquers and coatings
Some print films were (and some still are) coated with a protective layer of varnish-like lacquer to protect them from scratching. If a film is coated it can usually be detected on either side under a hand lens either from the edges where the coating appears to chip away or from fine drying marks or patterns that make the surface appear irregular or with a 'painted' appearance. Some films were coated on the emulsion side only, and others on both sides.

Solvent soluble coatings can be dissolved in isopropyl alcohol or by normal perchlorethylene cleaning fluid. These lacquers were applied from the mid 1930s on and were very common on early 1950s colour film. They could be scratched but if scratched it often did not extend down to the emulsion. The lacquer could be removed with a solvent (thus removing the scratch!) and the lacquer reapplied. Some of these coatings come off easily and others may need several solvent cleans. If this type of coating is found it is always better to remove it. It is usually pale yellow with age, and removing it will remove a proportion of the scratches. Permanent coatings are modern polymers, and are not removed by solvent (see the mention of Photoguard above).

Water cleaning
Water can be an alternative to solvents if the marks are water-soluble (Photoguard prints wash well), but this is difficult to test on the bench unless a piece of the film roll can be found with no image value. A cloth moistened with a mild surfactant or wetting agent such as Photoflo and water can be wiped across and the result inspected as before. This piece of film rarely dries uniformly and should not be re-used. The re-washing procedures used for emulsion scratch treatment are very effective cleaners.

Sufficient length of protective leader should be added to the front and end of each reel and the leader should contain sufficient information for the reel to be identified while out of its can. This would normally be the title, the reel number, a description of the material and any identifying number such as the location number or other ID number.

11.8.4 CFCs and the ozone layer

Solvent cleaning with 1:1:1 trichloroethane (1:1:1 TCE) has been the mainstay of all film laboratories for over 30 years. It is effective and fast, and replaced solvent cleaning with other more toxic solvents, notably trichloroethylene and carbon tetrachloride. The Montreal Convention has removed 1:1:1 TCE for the future and perchlorethylene is now used instead. There are a number of other solvents that archive laboratories have used for specialized cleaning purposes.

The Montreal Protocol on Substances that Deplete the Ozone Layer is the international agreement designed to protect the environment, with the power to ban substances that may be harmful to the ozone layer. The ozone layer is found in the stratosphere, between 10 and 25 miles above the ground. Ozone is a gas whose molecules have three atoms of oxygen (O_3). The molecules are spread very sparsely throughout the stratosphere but are nevertheless vital to the environmental system because ozone is capable of absorbing harmful UV-B ultraviolet radiation from the sun. Ozone is continually being formed and destroyed naturally because ultraviolet radiation from the sun breaks down oxygen (O_2) molecules into two atoms which combine with other oxygen molecules to form ozone (O_3). Ozone molecules in turn break down to produce O_2 and the process begins again.

There has been some difficulty in finding an alternative film cleaning solvent which has all of the benefits of trichloroethane without the ozone depletion problem.

Perchloroethylene is more toxic and less efficient as a cleaner but has been selected by several film cleaning machine manufacturers as the successor to 1:1:1 TCE. In Sweden another solvent is being used as the alternative.

11.8.5 Perchloroethylene (Perklone or Persolve)

This is a good film cleaner but toxic and with an unpleasant odour. The low evaporation rate causes some problems with drying at high speeds. It decomposes in heat to form poisonous phosgene gases and hydrochloric acid. The vapour is heavier than air. (This solvent is also used by most laboratories for wet gate printing because the refractive index, 1.506, is close to that of film base; see Chapter 13 on printing.)

11.8.6 Other solvents

A number of other organic liquids are regularly used in film laboratories for a variety of purposes. **Isopropyl alcohol** is used in one commercial film cleaner, and is used to clean joiners and work tops.

11.8.7 Safety

Considering the extreme volatility of the solvents most widely used in the cinematographic laboratory (perchloroethylene, isopropyl alcohol, and acetone, for polishing and cements), it is imperative to guarantee an efficient ventilation system. A monitoring method for their concentration in the atmosphere is essential, and a health and safety policy. Staff must be trained to handle both the solvent and the monitoring method. The machines that use these solvents must be connected with the correct ventilation systems. Respiratory-protection devices such as masks with active carbon filters are essential during tank cleaning and accident spills.

Several solvents in use are not flammable under normal conditions but it is still possible that contact with a naked flame would produce acidic and/or toxic gases and all naked flames or cigarettes are absolutely unacceptable. Chlorinated hydrocarbons decompose in heat to produce hydrogen chloride, carbon dioxide, carbon monoxide and, under very strong heat or strong ultraviolet rays, phosgene. Cleaning of tanks or containers that have contained flammable solvents should only be undertaken away from enclosed or poorly ventilated spaces and away from any ignition sources. Empty drums should never be cut by welding torch.

Prolonged contact with the skin should be avoided as powerful solvents will remove the natural greases. It is advisable to wear neoprene gloves when hands are exposed to the liquid. Safety glasses should be used if there is any chance of splashes.

First aid relating to any solvent exposure

- Remove the sufferer to fresh air.
- Obtain medical attention at once.
- Use artificial respiration if breathing stops.
- Oxygen may be administered if necessary.
- If solvent has been swallowed, induce vomiting (by tickling throat with forefinger or by compelling the patient to drink lukewarm salt water or warm soapy water).

Handling and storing solvents

A cool place using mild steel, cast iron or galvanized iron enclosed containers or tanks is recommended for most solvents but individual requirements should be checked. Small quantities of non-inflammable solvents can be kept in glass containers (usually as supplied).

All storage containers must be labelled with the contents.

Most film laboratories and some modern cleaning equipment use some form of distillation for re-use of solvents used in large quantities. The newer solvent cleaning machines incorporate their own integral re-distillation unit, but inevitably there will always remain some solvent for disposal. Flammable solvents require special transportation and fire protection during disposal and must be kept in special (usually) stainless steel containers with special ‘anti-flash’ closures.

The Control of Pollution (Special Waste) Regulations 1980 applies in the UK and carriers of controlled waste must register with their local Waste Regulation Authority. In all other EC countries there are equivalent regulations and authorities.

11.9 FILM CLEANING METHODS

11.9.1 Solvent cleaners – hand cleaning

Hand cleaning will always be needed for fragile film or seriously dirty damaged film that must be cleaned prior to repair. The usual method is as follows:

A non-abrasive cloth such as Canton flannel or a deep pile cotton plush or velvet should be moistened with the film cleaning solvent, perchlorethylene. The cloth should then be folded in two around the film and the film drawn through the cloth at a sufficiently slow speed that the solvent evaporates before the film reaches the take-up roll. When the cloth dries it should be refolded in order to use a clean surface, re-wet with solvent and the operation continued.

Gloves must be worn to protect the hands from the solvent's drying effect on the skin.

It is essential that this be carried out in an area specifically designed for this job with a high flow of extracted air across the film and away from the operator. The level of the solvent in the atmosphere must be monitored and kept below the statutory concentration (TLV; threshold limit value) for the compound. Manual cleaning should be done sparingly and only when absolutely essential, usually on very delicate film or very persistent individual marks. Mechanical cleaning machinery available today can clean almost anything with very low risks of damage and can be run slowly for maximum effect.

11.9.2 Ultrasonic solvent cleaning machinery

These cleaning machines, made by a number of manufacturers for film cleaning world wide, work on the principle of 'cavitation' similar to low pressure boiling induced by ultrasonic generators. The ultrasonic emissions in warm solvent create large quantities of minute bubbles which contain vaporized liquid. The bubbles are unstable and collapse, releasing energy in the form of shock waves which shock the immersed film and the attached dirt providing an intense surface scrubbing action.

Most modern cleaners run at 50–350 ft per minute; the immersion time is only a few seconds and the subsequent drying time even less. Perchlorethylene, lost to the atmosphere during drying, may be recovered from the extracted air. Eventually the solvent bath is so contaminated that it no longer cleans and before this point (in a well-run establishment!) the solvent is changed, and in most cases reclaimed by evaporation and redistillation, and used again.

There are several manufacturers of ultrasonic film cleaners, including RTI in USA, CTM in France, and Lipsner Smith in the UK. Some units use a rotary buffer on the film as it is immersed in the solvent to lightly scrub the film, and remove loosened dirt and grease, in combination with the ultrasonic generator, and these undoubtedly are most effective. However, damaged film, even well repaired, can be further damaged if sharp projecting edges catch on the buffers, and most specialist laboratories have a cleaner without the buffers for fragile film.

Drying the film after solvent cleaning is by air knives in an enclosed 'drying tower' after the film leaves the cleaning solution. The knives produce an even drying across the two surfaces of the film with no streaking. Air knives are slotted tubes which emit a stream of clean air and are usually of a design to extract solvent from the surface by the Venturi effect, a mechanism that reduces the air pressure locally at the surface of the film by the action of an air jet.

11.9.3 Clean-band solvent cleaner

A practical solvent cleaner design that avoids the problems of buffers and the excessive contamination of solvent from very dirty archive film uses a cotton band or bandage in a roll, wet with perchlorethylene, that slowly wipes the film surface running in the reverse direction to the film transport. The cotton band is used only once before being discarded. These cleaners are very effective for very dirty film, and are surprisingly economic.

11.9.4 Maintenance of solvent cleaning machines

Many solvent cleaners today work on a 'batch' principle and the cleaning solution in the machine will eventually become contaminated with soluble substances and will therefore lower the efficiency of the cleaning operation. Replacement with fresh solvent is necessary to maintain high standards of cleaning and in the most recent machines this is carried out transferring the dirty solvent to a distillation chamber and returning it to the cleaning tank after distillation. Modern film cleaners have built-in distillation systems, which take a few hours to regenerate the solvent in the tank.

Cleaning machinery requires regular and high quality maintenance. Regular checks should be made on the colour of the fluid as colour is one of the best indicators of contamination. A single roll of film with a varnish lacquer can seriously contaminate a solvent bath.

As with any transport system, badly maintained cleaning machines can scratch film and so film of no importance should be used as a test roll.

11.9.5 Particle transfer rollers

Several commercial designs exist using the special surface character of a soft polyurethane material (technically said to have 'Shore A' character), originally designed by Eastman Kodak. The roller surfaces made from this material are 'tacky' and remove dust and other particles onto their surface. The degree of 'tackiness' is determined by the choice, softness and surface texture of the roller's coating. The rolling contact with the film and the cushioned surface of the roller provide a low risk of film damage by scratching.

The principle was patented by Eastman Kodak as Kodak PTR (Particle Transfer Rollers), but such rollers are now made by a range of manufacturers.

When the PTR is fully loaded with dirt, after a few thousand feet, they can be washed with water or wiped with a damp sponge to remove the accumulated dirt (or a material with a surface stickier than PTR, such as adhesive tape can be used).

These rollers are now extensively used in the film path of projectors, printers, processors and telecine units to clean film of loose particles. The result is cleaner images, less 'sparkle' and also reduction in the build-up of dirt in the mechanisms of the equipment. They can be fitted to any negative handling equipment or used as a 'stand alone' film cleaner wound by hand or powered. They seem to work as well at any speed; for example, they are effective at 600 feet per minute on high speed panel printers.

In order to operate effectively there must be continuous intimate contact between the film and roller. The angle of wrap is unimportant and can range from only a few degrees to over 180 degrees. The tension is not critical but should be sufficient to ensure that good contact is maintained. These cleaners do reduce the amount of dirt on modern film and restorations but they will not eliminate the need for liquid cleaning of archive film.

A number of units on the market consist of a powered rewind transport that passes the film through a number of PTR rollers. These units are useful to conventional laboratories and for cleaning modern restorations of archive images but are not effective enough for cleaning old archive film.

12

Sensitometry and quality control

12.1 GENERAL AIMS OF QUALITY CONTROL

Clay and Walley in *Performance and Profitability* (London, 1957, p. 28) provide the following definition of quality control:

> Quality control is a system for measuring and recording the variables that affect quality in a methodical manner, so that the values and trends can be compared with standards and thus act as a means of control.

Quality control, then, is a system that provides information to management – the actual control, however, is exercised by management and not by the system. The aim of the system should be to make available the right information at the right time so that any decisions taken may be more meaningful and certain. In effect the quality control procedures can be seen as occurring in three separate stages. The first, often called **monitoring**, is measuring relevant useful information about the product or the process; **decision** is the process of estimating the action; and **control** is procedure of making the adjustment to the process.

Most manufacturing industries rely on 'statistical quality control'. Fault probability is linked to the number of component stages in manufacture and the reliability of each of those stages. If, for example, four stages (or components) are involved and each of them is only 80% reliable, then the reliability of the final product is only 41% reliable (0.8 to the power 4). Clearly, the reliability required is governed by the nature of the produce and its price. It is as futile to establish too high a standard as it is undesirable to establish too low a standard. In practice, the method used to monitor the production will be either by sampling or by 100% inspection. Where the latter is practised (as often it must be) by human skills, the effective inspection is likely to be less than 100%. Tests have shown that different inspectors will reject different items, and the same inspector will reject different items at different times of the day!

In this chapter, as in the reality of film laboratory life, there is a sharp distinction made between what is called quality control, that is the procedures needed to monitor and thereby control the individual machines, chemical processes and photographic stages, and quality checking, which is carried out at the end to visually appraise the total success of the entire sequence of restoration.

All monitoring is made more objective if the characteristics of the process can be converted into numbers, and these parameters are widely used in quality control, but almost never in quality checking, mainly because of the subjective nature of vision.

As a result of the quality control techniques in use, it is possible to plot graphs which indicate the stability, drift or random fluctuation of any manufacturing process. Such graphs normally incorporate various limits for managerial guidance – these are usually called 'action limits' and 'control limits'. Sometimes a special lower limit is known as a 'warning limit'.

Quality control should not be considered in isolation and the temptation to see it as an end in itself must be resisted. Good quality control requires effective liaison between all other departments and control technicians must never lose sight of the fact that a laboratory exists to produce film, not to provide work for a Control Department.

12.2 PHOTOGRAPHIC QUALITY CONTROL

The most effective monitoring of the production procedure in photography is by sampling (in effect what the control strip does of a photographic process). One hundred per cent inspection methods, as far as individual printed or processed frames are concerned, is almost always impossible and often only relevent later in the sequence. Sample information on stages in the procedure can be plotted graphically so that management can be aware of any changes that occur, can avoid operating outside the control limits, and can instigate remedial action when necessary.

The definition of quality control above does not explain purpose, which is usually twofold: first to ensure that the product is of the highest quality, and secondly to ensure that the quality is maintained consistently. Consistency is paramount in that procedures such as grading can only be satisfactory if the grader can be sure that a particular set of printing conditions will give identical results from day to day and year to year. Similarly, a print made today should be able to be made with the same grading in the future and be visually the same.

Monitoring of the various production stages in photography is always a sampling procedure, and is always devised to provide control decisions. At the end of the final stage of restoration there must come a quality check on the end product and in the case of fairly routine restoration where the image is being preserved because the film base is breaking down but the subject is not of major importance, then it is inevitable that only samples of the product are viewed, or the projection is visual and relatively cursory. One hundred per cent checking of the final end product becomes more relevant the more costly or significant, in cinema or historical terms, is the subject matter.

In the 1960s the Eastman Kodak Co. in the USA was having problems with the quality its photofinisher laboratory customers were generating when producing paper prints for the amateur market, and a special Quality Control Manual stated that

> the quality standard should be such that the negatives, transparencies and prints produced will create good will, repeat orders, and the respect of customers. It should be flexible enough to allow for improvement whenever possible, but inflexible to the extent that no compromise with poor quality will be tolerated ...

This policy is one to which any motion picture laboratory aspires today and also one which can be appropriate inside an archive since there can be internal customers just as easily as external ones.

Shortly after Eastman Kodak introduced the Eastman Colour Motion Picture films in the early 1950s the company started a unique control service to all the laboratories in the world that were to process Eastman Colour and were their direct customers. The service, known today as the Eastman Colour Interlaboratory Survey, provides standard control strips to the laboratory which it processes, keeps one as its own reference and returns one to the local Kodak organization running the scheme. The strip is read and analysed by Kodak and data returned to the laboratory showing how far the customer's process is from the Kodak standard (and giving the process an A, B or C rating). This is the only 'absolute' control standard provided by a manufacturer in this industry. Customers have an opportunity to check their own aim values from this scheme every few months. This system monitors the process only.

Certain prerequisites are necessary for any control system to function satisfactorily:

1. The personnel responsible for quality control decisions must have a good knowledge of the photographic process to interpret their findings and the resolution and seniority to see that these are acted upon.
2. The production system itself must be set up correctly before the control system can operate efficiently.
3. The materials used for control purposes must be beyond reproach.
4. It must be understood that when a control reading is out of tolerance then the customer's or internal customer's work is similarly affected. If the work appears unaffected then two possibilities arise:
   (a) that two of the control factors are proving to be self-cancelling – this is an unstable and dangerous position to be in; or

(b) that the reference or aim point is wrong.

Quality control in the printing and processing of any photographic materials requires similar objectives to those used in the original manufacture of the products. Among these are acheivement of correct speed, colour balance, contrast, freedom from physical defects etc., and provided that there is an appreciation of what the objectives are, and the characteristics of a 'correct' result defined, then quality control can become just another routine.

Motion picture film processing consists of mechanical, photographic and chemical stages resulting in an image that has to be evaluated. The chemical stages can be controlled by means of analysis, the photographic by means of densitometry and sensitometry. However, the final result is a picture image or sound that has to be looked at or listened to, and that fact should never be forgotten. Every numerical parameter must be related to the visual image and there is no value in measuring film parameters that do not. To put this the other way round, it is essential to find numerical values that correspond to visual characteristics of images so that these may be used to monitor the quality and the consistency. In a number of applications the image being handled could be a negative, intermediate positive or a sound track, none of which has a relevant visual character at this stage, but eventually the final visual [or audible] character will become relevant further down the generations and the monitored parameters of these intermediate materials have to relate to these final images or sounds.

A few of these variables at different photographic stages are:

- **Processing:** the variables of machine speed, temperatures, formulae, replenishment rates and formulae of replenishers, contaminants, water supply, all effect speed, density, contrast, and colour of the result.
- **Grading:** the variables of viewing light sources, screen and room conditions, analyser set, calibration and correlation, grader's vision.
- **Printing:** the variables of lamp and lamp voltage and current for picture and sound lamps, trim settings, filtration, and speed of printing, modifications from flare, halation and reflections, alter density, balance, colour balance and contrast.
- **Film stock**: different batches of film stock vary and need testing to ensure consistency and acceptability and to enable settings to be worked out for printing machines.

12.3 FILM MEASUREMENT

To review the technical aspects of quality control needed for the restoration of archive film it is necessary to first look at the parameters used to measure film characteristics. This will be followed by a review of standards and aim values, and finally control techniques. However apparently complex or parochial these measurements and control methods are, many, particularly of contrast, are essential to the procedures for good duplication. The section on duplication makes considerable use of the background information given in this chapter.

12.3.1 Sensitometry

Sensitometry is the science of measuring the response of photographic materials.

The response of film to light is one in which light energy causes a darkening in the emulsion. This generally takes place in two stages:

1. Exposure to light (where the darkening that occurs is normally of such microscopic proportions as to be invisible to the naked eye. This image is then said to be a latent image).
2. Development in which the exposed emulsion is immersed in a chemical solution capable of amplifying the latent image while leaving the unexposed crystals in the emulsion unaffected.

To measure the effect light has on film as seen on the processed film it is necessary to be able to measure both the amount of light (called the **exposure)** and the degree of darkening of the film (called density).

12.3.2 Exposure

The total exposure, E, which a piece of film has received is defined as:

$$E = I \times t$$

where I = intensity of exposing light (usually in metre candles) and t = exposure time of the shutter (in seconds). Thus exposure units are metre candle seconds.

The density produced on a film by a given exposure is almost always the same whatever the differing values of intensity or time. This relationship is known as the Reciprocity Law and is substantially obeyed by photographic materials over the normal exposure range for which the material is designed. However, at very high intensities and very short times or at the other extreme at very low intensities and very long exposure times there are deviations from the Reciprocity Law with most materials. This phenomenon is called Reciprocity Law Failure but is rarely relevant to our technology.

12.3.3 Density

If a sample of transparent or semi-transparent material such as processed film is illuminated

(*a*)

(*b*)

Figure 12.1 (*a*) A manually operated colour and black and white transmission densitometer, Macbeth TD 204, for general use. (*b*) An automatic step plotting densitometer combined with a Windense software package for Status A & M control of colour processing printers and duplication by light of intensity I and the intensity of light transmitted by the material is T, then

$$\text{density} = \log_{10} \frac{I}{T}$$

Density was originally expressed as a logarithm to the base 10 simply because of the convenience of doing so; however, the human eye responds to light intensity in a logarithmic way and, for example, a grey scale in which the density increments are in equal units, appears to the eye to have 'equal' visual steps. The human eye responds more or less logarithmically to changes in light intensity. In other words, equal changes in light intensity do *not* appear equal over a wide range of intensities, whereas equal changes in log (intensity) (log I) appear almost equal over the whole visible range.

For carrying out all photographic response calculations it is conventional to work in terms of density and $\log_{10} E$.

Quite apart from the visual equivalence, log values have other benefits. If linear units were used, any graphs plotted would have to be enormously large in order to have sufficient scale magnification at the low end of the scale. A further benefit of using logarithmic units of exposure and 'light-stopping power' is that it provides a simple relationship between them. For example, if the density of filtration in the light beam of a printer is increased by 0.1 density units this will reduce the log E also by 0.1, assuming the exposure time is kept constant.

Changes in log E are also easy to relate to camera *f*-stops. Since $\log_{10} 2 = 0.3$, a change in exposure of one camera *f*-stop is equivalent to a change of 0.3 log E, a change of two *f*-stops gives a log E change of 0.6 and so on.

If a strip of film is given a series of exposures and after processing the densities are measured a graph of the response of the film can be plotted.

12.3.4 The characteristic curve – monochrome films

The convention used throughout photography is to plot the D log E curve on the same x and y scales. This ensures that it is easy to compare one film stock with another by visually comparing the response curves. These are called **characteristic curves** or **H&D curves** after the originators, Hurter and Driffield.

The average photographic subject will not use the full range of the camera negative material's scale. The section that is used depends upon the **image brightness range** which, in turn, is dependent upon the **subject brightness range** and the **flare factor** (the degree of light scatter of the camera system that results in stray non-image light striking the film). The 'average' subject in sunlight has a subject brightness range of about 160:1. The average camera has a flare factor of 2.5, which means that the image brightness range is reduced to 64:1. In terms of log E, 1.8 log E units of the characteristic curve ($\log_{10}$ 64) will be used by that subject,

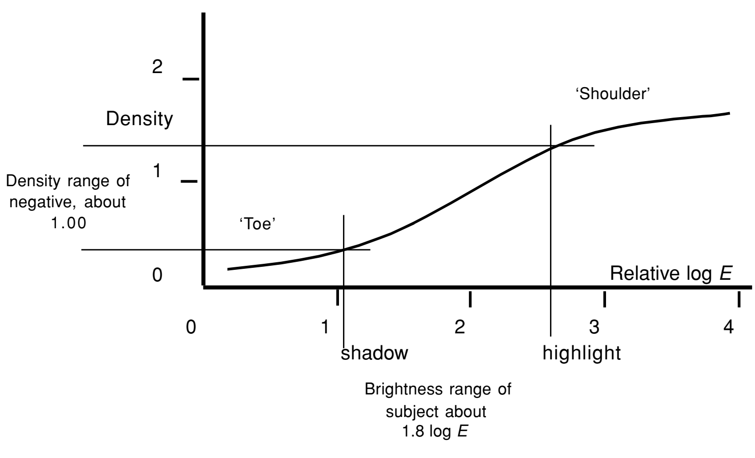


Figure 12.2 Typical characteristic curve of a black and white negative film, showing the range of exposures from a typical subject

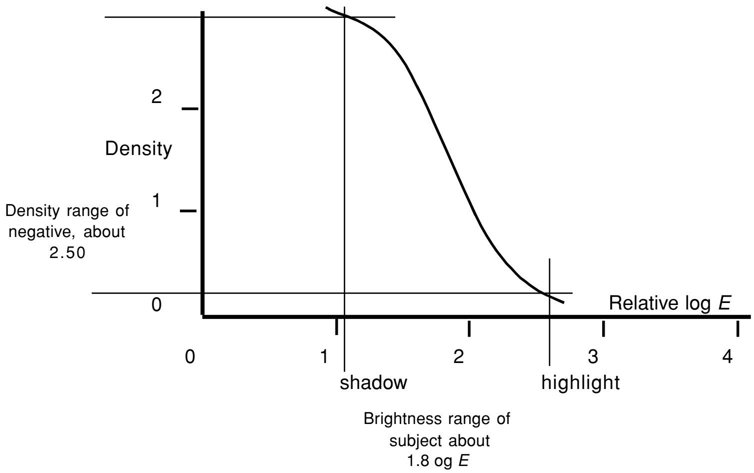


Figure 12.3 Typical characteristic curve of a black and white reversal film, showing the range of exposures from a typical subject

extending approximately from a point on the toe to a point on the straight line.

If the film material in question is capable of producing a change in density over a total log *E* range of 3.0 units, then obviously 1.2 units are unused by this subject. This represents the latitude of the material and would in this case be equivalent to four stops of camera exposure (1 stop = 0.3 log *E*).

In the photographic positive, the best visual effect occurrs when the whole of the density range is used as this gives the maximum tonal range in the reproduction.

A negative processed film, whether it is a negative or positive image, is said to have a negative curve (i.e. low density at low exposure); a reversal processed film, whether it is a negative or positive image, is said to have a positive curve (i.e. low density at high exposure).

Parts of a curve

It is common to talk about the various parts of a characteristic curve using rather anatomical analogies!

- The **toe** of the characteristic curve is the region where the density is slowly building up its response to light. Some of the shadow detail of the subject will normally record on the toe of a film.
- The **straight line** is the region where density is increases in a linear uniform way with increasing log exposure. Both the length and steepness of the straight line are largely determined during emulsion manufacture, although the angle of the slope is also dependent upon the level of development. Older materials were designed with as long a straight section as possible (especially negatives) but it has been recognized over the past 20 or 30 years that this is not a prerequisite of a good quality picture. Some modern materials are markedly ‘dog-legged’ or ‘hunched’.
- The **shoulder** of the curve is reached when the rate of increase in density with exposure begins to diminish until no further density increase occurs – the value at this point being termed the D_{max} which is dependent upon the emulsion and its level of development. If the development has been taken to its limit, then the D_{max} obtained will solely depend upon the quantity of silver salts employed in making the product.

A variety of relevant parameters can be calculated from characteristic curves. Parameters are numerical values for certain characteistics of photographic emulsions and it is important that these parameters are relevant to the way in which a film is used. Speed, contrast, D_{max} and colour balance are all parameters that are useful for describing films and are all calculated from the characteristic curve.

Calculation of speed

The speed point is a point on the curve from which the parameter called speed is measured.

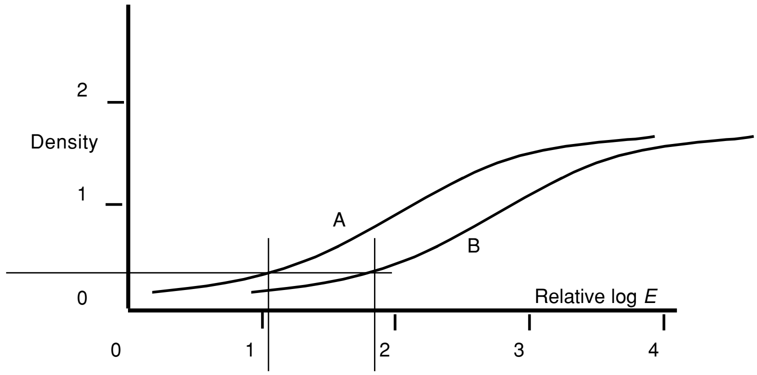


Figure 12.4 Film A is faster than film B, i.e. it requires less exposure to produce the same density

Speed is the term for the sensitivity of a film emulsion to light, sometimes called general sensitivity.

The usual method of calculating a speed value is to define a speed point as being a particular point on the curve defined by its density and to read off the log *E* value it corresponds to. This will give a value that increases in numerical value the higher the log *E* needed. Since to our senses 'speed' implies a higher value the less the exposure needed to achieve a specific density, the number is usually subtracted from a fixed value to give such a scale, and then multiplied by some convenient number to avoid decimal points. Such is the relationship between speed and photographic speed!

For example, the speed rating of Eastman Colour Negative Film, as used throughout the world, is:

$$ER = 100\ (1 - \log Es)$$

where log *Es* is the log *E* value corresponding to a point on the characteristic curve 0.10 above D_{min}. There will be three *ER* values, one for each curve, R, G, B. In practice this formula will result in a number somewhere about 250. This absolute value is thus a combination of a precise log *E*, at a precise position corresponding to a low shadow exposure, expressed in a formula that is simply a convenient convention.

Speed values used by the cameraman to determine the correct camera exposure are often quite different from those used in laboratories For example, two of the current methods used for camera work are called after the standards institutes that devised them. The ASA (American Standards Association, rating of a film is based on the amount of exposure required to produce a density of 0.1 above the fog level (in exactly the same way as *ER* above). Development has to be in a specified formula developer at specified conditions, for monochrome and at the manufacturers process conditions for colour. The calculation used is different from that of *ER*.

The ISO (International Standards Organisation) value is identical in principle and value to the ASA. DIN (Deutsches Industrie Normaliche) is another similar system but whereas the ASA and ISO are arithmetic series, the DIN is a logarithmic speed series. In arithmetic series the speed value doubles with a doubling of the actual speed. In a logarithmic speed the speed value increases by 3 (log 2) when the photographic speed doubles.

In archive restoration work little value is placed on absolute speed and only relative differences are useful. A technician needs to know that batch A is two printer points faster than batch B, or that a process has altered in speed by one printer point. The exact speed in ISO/ASA is of no interest. The manufacturers quote speed ratings to laboratories in terms that are unique to the stock. Camera materials are given speed ratings which are absolute as indicated above, but printing materials are usually given relative values. Kodak uses, for example, the term Relative Printer Rating (RPR).

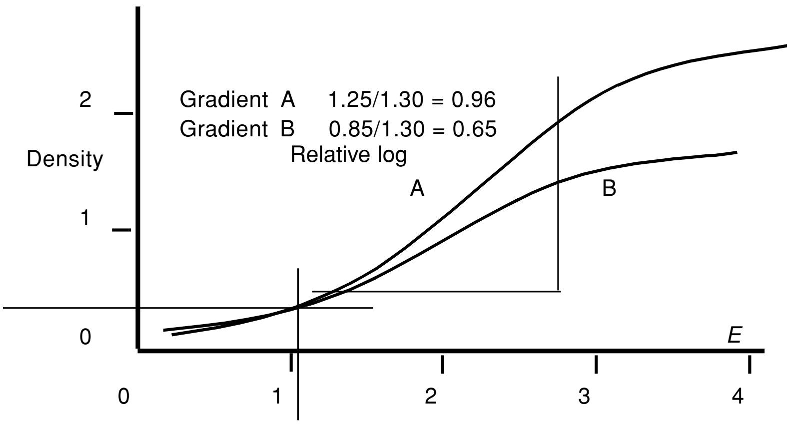


Figure 12.5 Film A is higher in contrast than film B. Contrast is measured as the gradient or slope of the curve. The speed is about the same at the low speed point

Contrast

Contrast is the visual effect we see from the range of white to black as it corresponds to highlight and shadow. Contrast is usually measured as the slope of the characteristic curve and in early literature this was usually described as the slope of the straight line portion of the curve in the centre. Often this portion of the characteristic curve of a film is not completely straight, and so contrast is frequently measured today as an average slope over that part of the curve. The methods of calculation are often different for different types of film in order to obtain a value which most closely represents the effective contrast under normal conditions of use.

The slope of a straight line section is known as γ (**gamma**). The term gamma has now been truly fossilized in our terminology, its original meaning (and its present day mathematical meaning) of the slope of a straight line, has been largely forgotten and many film technicians talk of gamma when what they really mean is the contrast of a material with no true straight line and whose contrast is measured by some other method.

Many modern materials often do not have these straight line sections and colour materials almost never so that other parameters are used to calculated average slope. These parameters have been given various names or symbols; α (**alpha**), the slope of a line drawn between two points on a curve is the most commonly used parameter for contrast (also called average gradient or AG), and, since the toe of the curve is also important, other

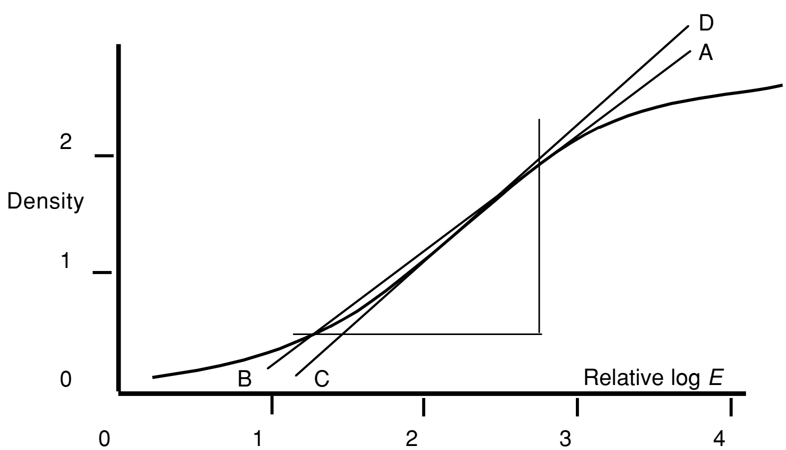


Figure 12.6 Here, gamma is the gradient of the straight line section, DC, and is higher than the slope of the line between two points on the curve, AB, the average gradient, or average contrast

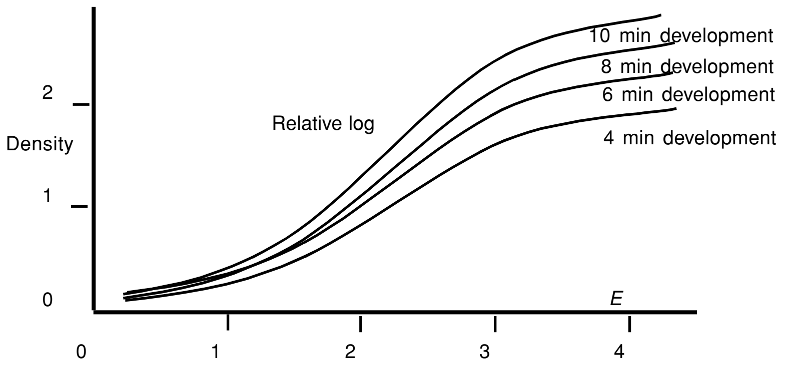


Figure 12.7 If a film is developed for longer the contrast increases

measures have been devised to take these regions into account. **Contrast index** is a measure devised by Eastman Kodak. It can be measured by laying a special meter over the curve. The numerical value is always slightly lower than gamma would be on a straight line. These averaging methods are sometimes called **best fit contrasts** or β **(beta).**

The link between contrast and development time for any particular emulsion can be displayed on a 'time–contrast' curve. The longer the development time the higher the contrast produced. Colour materials also increase their contrasts with increasing development time but this is rarely relevant as the three layers do not increase in contrast at the same rate. This means that there is only a narrow development range over which the three layers produce similar contrasts.

Maximum density (D_{max}) and minimum density (D_{min})

D_{max} of a negative film is the density at which further increase in exposure fails to cause any further increase in density. For a reversal film, D_{max} is the density of processed, unexposed film.

D_{min} of a negative film is the density of processed, unexposed film. For a reversal film, D_{min} is the density at which further increase in exposure fails to cause any further reduction in density. Also called **fog level**, this is the level of least density recorded on the film after processing – i.e. in an area that has received no exposure. Normally, this also includes the density of emulsion support and this may well contribute the greater part to the so-called 'fog level'. True fog level varies with different product types, the age of the emulsion and processing conditions and chemistry and is strictly the lowest density of the emulsion. Sometimes the term 'stain' is used to describe the lowest density above that of the base. The D_{min} may indeed result from genuine chemical staining, especially on archive film, rather than silver or dye, but all these terms are widely confused. It is best to use the term D_{min} only.

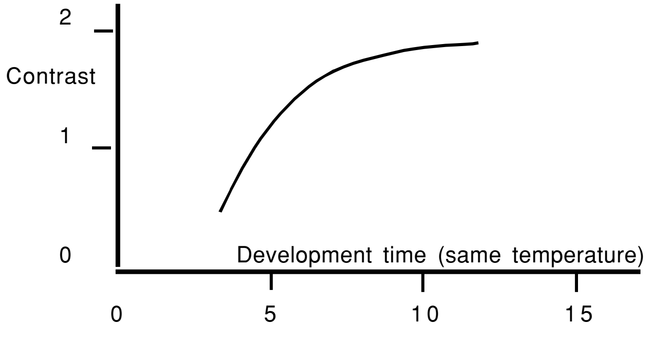


Figure 12.8 Development time–contrast curve of a black and white emulsion

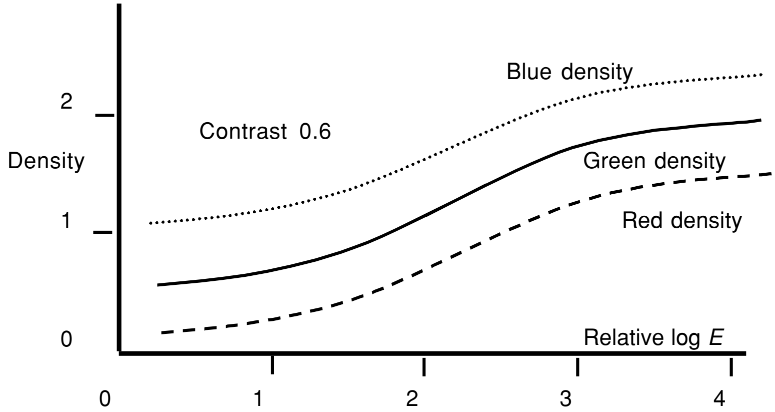


Figure 12.9 Characteristic curve of a typical modern colour negative film

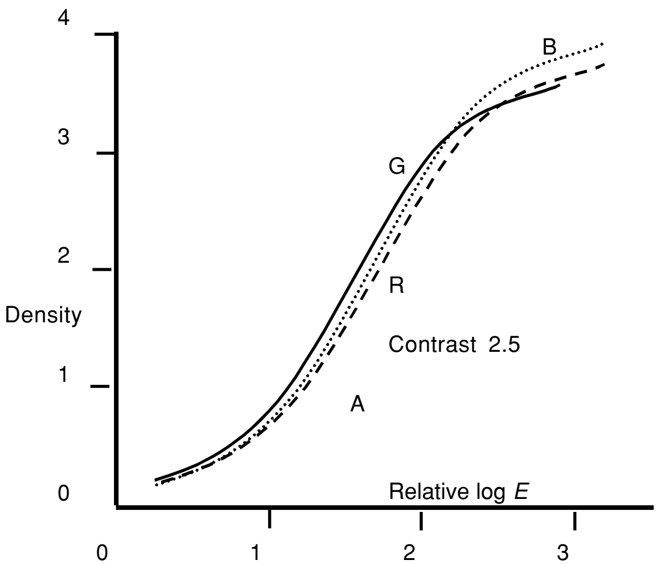


Figure 12.10 Characteristic curve of a typical modern colour print film

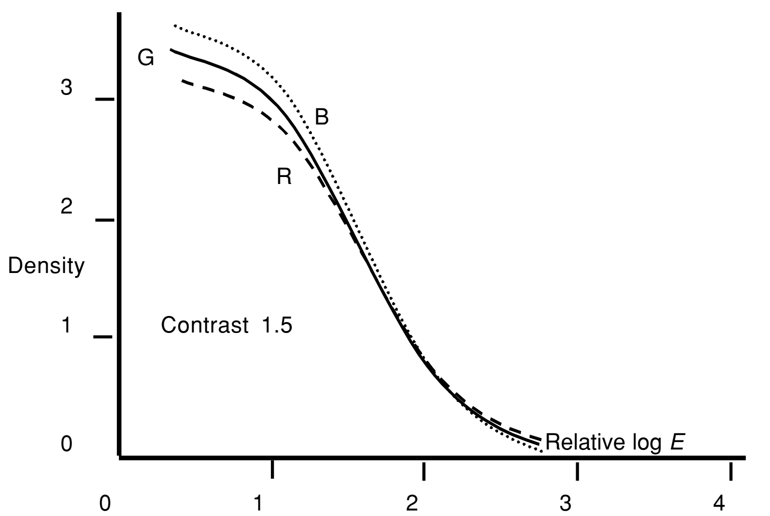


Figure 12.11 Characteristic curve of a typical modern colour reversal camera film

12.3.5 Characteristic curves of colour films

To prepare a characteristic curve or curves for colour films it is necessary to measure the densities of each exposure step to red, green and blue light separately. One can then plot on the same graph three curves, one for each layer of the film.

In a colour negative film the three curves are separated vertically since the orange integral mask in the film, the overall orange-coloured base, has highest density to blue light, lowest density to red light. Colour print films are of much higher contrast (like black and white print films) but are characterized by three curves with a very low D_{min}.

In a colour reversal film there is no integral mask, therefore, the three curves are almost coincident.

12.4 THE PRODUCTION OF A CONTROL STRIP

12.4.1 Exposure

The fundamental practical element of sensitometry and control is the **step wedge** or **control strip**. It is a precisely exposed length of film with, in practice, usually 11 or 21 steps of exposure. The exposure will vary such that the strip will have blocks of image from clear film to totally black film.

A **sensitometer** produces these step wedges or strips. A sensitometer gives a precise, controllable and repeatable exposure. There are two types of sensitometer – **intensity scale** and **time scale**. Intensity scale sensitometers produce the variation in exposure by means of a master step wedge exposed by a precise amount of light, commonly by an adjustable slit passing the wedge at a constant speed. Time scale sensitometers produce the variations in exposure by different time exposures. This is usually achieved by a rotating disc with different size sectors cut out of the disc. Both types of sensitometer require lamps that have been calibrated to give a known intensity of light at a known voltage, usually less than the rated voltage of the lamp to give increased life. The lamps are run from a constant power source with an accurate voltmeter.

In most sensitometers for motion picture applications a fixed exposure time is used which represents the exposure time typically used in practice with the particular film in question, and therefore the sensitometer is of the intensity scale type. A strip of film is exposed through a step wedge or **step filter**, giving varying intensities of the light which cover the normal usable exposure range of the film. Because of the difficulty in producing accurate step wedges these are always calibrated by the manufacturer. For black and white work a photographic (silver image) wedge can be used, but for colour work where the image must be neutral the wedge is normally made from a dispersion of graphite particles in gelatine.

12.4.2 Working with absolute log *E* values

Control strips can be exposed in a sensitometer to provide a repeatable strip that is exposed with known increments between the steps but no precise value for the log *E* scale. Such strips are widely used to control print and duplicating material processes. However for controlling camera negative film processes a precise or absolute value for log *E* is used by the use of a calibrated lamp in the sensitometer and calculating the value of log *E* for one of the steps. This degree of precision is rarely, if ever, needed in the restoration of archival film.

12.4.3 Working with commercially available control strips

Some film stock manufacturers sell control strips already prepared and in foil packs for freezer storage. In general these are for colour processes, especially for reversal processes. The control strips have relative, not absolute log *E* values but the pack includes a ‘correctly’ processed strip that can be used as a reference against which to compare the process. Unfortunately precision-made control strips are limited to Kodak colour camera negative, positive and camera reversal films.

12.5 PRACTICAL DENSITOMETRY

To restate:

$$\text{Density} = \log_{10} \frac{I_i}{I_t}$$

where I_i is the intensity of light incident on the film, and I_t is the intensity of the light transmitted by the film.

The instrument used for measuring density is a densitometer. Densitometers have existed in many forms. The earliest are the null reading type where the light is split into two beams. One beam passes through the film and the other through an adjustable attenuator. The photocell is used to measure when the light from each beam is equal. Densitometers of the null type have been available where the eye is used instead of the photocell.

The commonest type of densitometer in use today is the photoelectric direct reading type. Light from a lamp is focused on the film being measured and a photo-sensitive cell measures the light passing through the film. Densitometers come in many forms. The earliest, the majority of densitometers used today, use voltmeters to measure the output of the cell directly and the most modern models have digital displays.

There are three different optical arrangements, sometimes called optical geometries, for density readings, and each produce a different density value from any film emulsion.

1. **Specular density**, where the light falls on the image normally and only the normal component of the transmitted light is measured.
2. **Diffuse density**, where the light falls on the image normally and *all* the transmitted light is measured.
3. **Double diffuse density**, where the light falling on the image is completely diffuse and all the transmitted light is collected.

In motion picture control **standard diffuse density** is used as it simulates practical use conditions of contact printing and small changes in the measuring geometry of the instrument have little effect on density readings.

The available density range of a motion picture densitometer with the filters removed should be at least 0–7.0 so that with the complex colour filters in place it should have a density range of at least 0–4.0. This covers the highest densities likely to be found with film materials.

For picture materials the recommended photocell is the S-4 cell or its equivalent. This has a response peak at approximately 550 nm to simulate the response of the human eye.

For soundtrack materials the recommended photocell is the S-1 cell. This has a response peak at approximately 800 nm, similar to the photocells normally used in projector sound track systems.

A tungsten lamp with a colour temperature of 3000 degrees K is normally recommended as this is a very stable light source. Modern densitometers sometimes use tungsten halogen lamps with a higher colour temperature than 3000 degrees K but the spectral response of other parts of the system is then modified to give the required overall spectral characteristics for the instrument.

The filters are very critical in some aspects of densitometry but the specifications are usually given for specific light sources and photocells. The Kodak 'Status' system is now universally used for modern materials and recommended for all process control.

12.5.1 Status densitometry

The status filter or filter set is specific to a product or emulsion type and is dependent on the use of the material.

- **Status V**: This is a single filter used to measure the density of monochrome positive films. The spectral response of the filter in combination with the photocell and lightsource produces a sensitivity similar to that of the human eye, hence V for Visual.
- **Status A and Certified AA**: These are sets of three filters, red, green and blue for measuring colour densities of positive colour materials. The filters and densitometer combine to have a similar sensitivity to the human eye. The original filters used were Status A. Some years ago as photocells were slightly altered Certified AA were introduced for modern equipment. Status A densities can be plotted on trilinear graph paper to give a display that indicates the visual hue

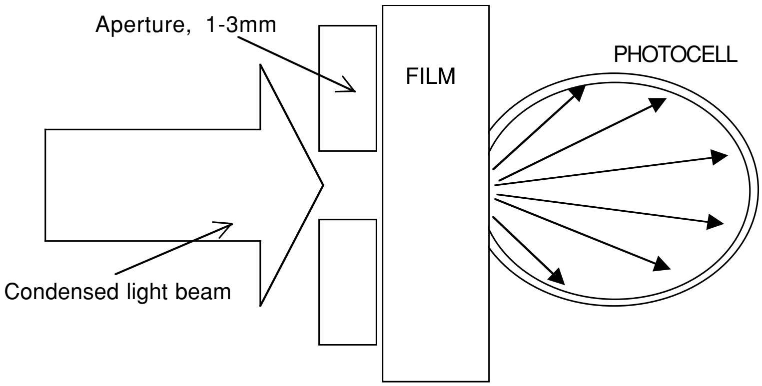


Figure 12.12 Standard diffuse density is measured when the incident light is specular (a parallel condensed beam) and all the light transmitted is collected by the photocell

and saturation of the patch, step or image measured. The brightness is not idicated on this form of display. This procedure is ideal for comparing different dye systems to see if they have similar visual appearances, for example in the reproduction of an old dye in a colour film to the reproduction of it by a modern subtractive colour film.

- **Status M and Certified MM**: These are sets of three filters, red, green and blue, for measuring colour densities of negative colour materials. The filters and densitometer combine to have a similar sensitivity to the Eastman Colour Print films. The original filters used were status M. Some years ago as photocells were slightly altered Certified MM were introduced for modern equipment.
- **Status S**: This is a single filter used to measure the density of sound tracks on print films. The spectral response of the filter in combination with the photocell and light source produces a sensitivity similar to that of the sound photocell of a projector, hence S for Sound. It is not used for measuring negative sound tracks.

Several other status filters are in use but the only ones likely to be seen in the motion picture industry are loosely called **Status D**. These are often fitted to densitometers used for still photography and are a reasonable alternative to both A and M but should not be considered very precise. Status D is quite good enough to use for comparative process control work but is not quite precise enough for setting up colour duplication systems.

12.5.2 Control of densitometers

In time, densitometer results drift due to changes in spectral emission of light sources (both colour temperature and output tend to reduce with age), sensitivity of photocell, spectral transmission of colour filters (filters may fade, or be damaged in use) and changes in the alignment of optics.

Densitometers are usually checked using a very stable filter or plaque that does not easily change with time. Several devices are available for this pupose including, for a full colormetric and photometric check, the Kodak Transmission Densitometer Check Plaque.

12.6 PHOTOGRAPHIC PROCESS CONTROL

12.6.1 Process control strip processing

Process control strips are made on a sensitometer in batches. They can be stored for periods up to 3 months in a freezer at less than –10°C without significant changes in image. However, it is usual to store freshly made control strips at room temperature, say up to 18°C, for two days, as the greatest changes in latent image occur within this period after exposure. This ensures that any changes that are to occur due to this latent image regression do so, and then the film can be stored without the likelihood of further major loss. Strips should be removed from the freezer a few hours before use to allow them time to warm up. Removing a cold strip from its packing usually results in condensation on the film surface. Strips are usually stored in small batches which correspond roughly to a day's use.

Control strips are processed in between rolls of film and therefore they receive the substantially the same chemical processing as the film. The frequency of processing strips depends on the laboratory standing orders, but should be at least every time the process is run and every hour or so when the processor is running continuously. Once processed the strip needs to be evaluated.

12.6.2 Interpretation of a process control strip

From the control strip a great deal can be interpreted. Absolute parameters, for example speed ratings, when the actual values of the log *E* scale are known, are used by some laboratories, especially if they are part of the Kodak Interlaboratory Survey. In the case of camera negative materials absolute parameters are essential but an archive laboratory does not use camera negative film (or, at least, not for camera images) and need not work with absolute log *E* values.

The most usual procedure is to calculate the parameter and then display the numerical value on a record sheet in the form of a running plot or clothes-line plot. It is possible, if a plotting densitometer is available or only a small number of strips need to be evaluated, to make a full plot of each process strip characteristic curve. However, in practice most laboratories operate with one of two routine methods.

1. Use an automatic plotting densitometer (like the X-rite) coupled to a computer program that calculates absolute (or relative) parameters and plots them as a computer displayed running plot for each process.
2. Use a manual densitometer, in which case absolute parameters are used occasionally, say once a week, to check the overall quality, and the daily routine control strips are monitored using the fixed step method.

12.6.3 Fixed step process monitoring

This procedure requires that there exist a correctly processed strip that can be used as the reference strip. The reference is either a strip supplied with a commercially available pack, or it can be a strip that corresponds to the aim for the absolute parameters the management believe is correct, or it can be a strip processed with an Interlaboratory Survey Strip and its correct values interpreted from the Survey report. In the case of Eastman Colour, this last method is the most used by commercial laboratories.

Fixed step control simply requires that a number of steps on the control strip are measured in order to plot their variation from the reference on a running plot against time. A typical set of steps could be:

1. A step corresponding to the minimum density (D_{min}). This is the density of the film where there has been no exposure. The density obtained will be the result of chemical fog from processing, exposure to light during manufacture and during use in the laboratory.
2. A step corresponding to or near the speed point. For example close to a point 0.1 above D_{min}, in the case of a negative film.
3. A step corresponding to or near the upper point used to calculate the contrast. For example at a point corresponding to the highest exposure from an average 1.8 log *E* subject brightness range.
4. A step corresponding to the maximum density (D_{max}). This is the highest density the film can produce and will depend on the amount of silver or dye in the film.

In order to show a value that corresponds more closely to contrast, rather than just a single upper step, the value plotted on the running plot is the difference between the upper and the speed point, or Step 3 – Step 2 above.

12.6.4 Running or clothes-line plots

The clothes-line plot will display the variation of a parameter or fixed step from occasion to occasion and can show whether the steps we are measuring are within a set tolerance or not. The example in Figure 12.13 uses four fixed steps plotted as a running plot of a process.

The control limits, or tolerances as some manufacturers call them, are shown as dotted

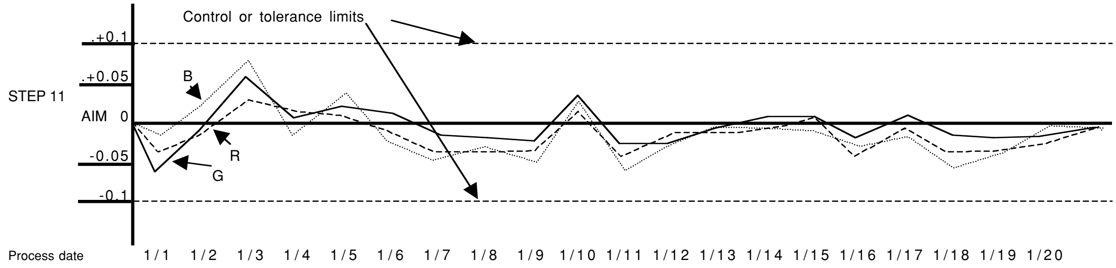


Figure 12.13 Typical running or 'clothes-line' plot of a colour process for one parameter, Step 11, on a process control strip

lines above and below the aim point horizontal axis. These limits are set by manufacturers as being compromises between achievability and being visually noticeable.

12.6.5 Physical control of the processor

When one or more steps is out of tolerance it is necessary to make a careful analysis to determine the cause. The most common cause is a change in the activity of the process. The most likely are alterations of machine speed or developer temperature. The effects of temperature rise and fall of machine speed are similar for black and white stocks, giving increased density and contrast. The opposite effects are produced by a rise in machine speed or fall in temperature.

Change in machine speed or temperature can affect the three layers of a colour film differently, leading to contrast mismatches. The contrast of each layer alters independently so that instead of a grey scale from white to black the scale could appear grey with pink highlights and green shadows or other combinations. Such a mismatch is out of tolerance. For this reason the speed or temperature of a colour process cannot be varied from the manufacturer's specification to any great extent. The speed and temperatures of a black and white process can be varied to alter contrast.

12.6.6 Chemical control

Chemical changes can also cause activity change, and changes in D_{min} or D_{max}, or if some steps have risen and others have fallen, these are characteristically due to changes in chemistry. A good knowledge of photographic processes and the action of each bath may help to track down the cause. However, this is not normally the technique used to correct chemical problems.

Chemical control can be basic or advanced according to the equipment available as well as the skill and knowledge of the operator. Large laboratories have elaborate systems primarily because they have more to lose if something goes wrong; small laboratories may appear to take more risks by doing less but errors and drifts are simply more easily corrected.

This book is not the place to look at the complexities of full blooded chemical control in which each solution is analysed, replenisher formulae are subtly altered and tight control exercised. In the smaller laboratory this degree of detail is out of place and is replaced by two measurements that, properly evaluated, can tell an experienced operator a great deal.

These two simple values are specific gravity and pH, and they make it is possible to tell whether a solution is in or out tolerance, but not what is incorrect. The formula for each solution will give an aim figure for pH and specific gravity and a tolerance. The SG reading indicates if the solution has the correct quantity of chemicals dissolved. If one chemical is left out of the solution a lower than aim SG reading is obtained. The pH value of a solution is an indication of the solution's chemical activity, especially in the case of a developer, but details on these measurements are not appropriate here.

Both SG and pH are also widely used as checks immediately after mixing a fresh process solution or replenisher to establish in a crude but effective manner whether all the components were remembered!

The general principles of chemical control are not that of identifying a photographic problem and knowing how to adjust the chemistry to correct it. The variations possible are so great that it is rare for even the best chemist to be able to control a process that way. The practice is that each solution has a standard analysis formula, one that has been found produces the optimum result. Most of these are defined by the manufacturer and, in the case of colour processes, almost all are defined by Kodak. In the case of most developer solutions and developer replenishers the standard manufacturer's formula needs a little adjustment to keep the correct sensitometry.

The job of the process chemist is then to carry out a regular routine analysis of the solutions and, **when they depart from the standard concentrations**, to adjust them back to those standards.

12.7 PRINTER CONTROL

Printer light sources and sometimes the optics vary over time, although it is primarily the lamp that changes in intensity and colour quality. Monitoring the printer is carried out in order to set the light source back to a common position. Thus a print made today can be reprinted tomorrow without excessive re-testing. Many laboratories set the light sources of all the printers in the laboratory to a single common intensity and colour balance so that any printer will print any previously graded film without adjustment. This is really only possible with printers that have the same light source construction, such as a Bell and Howell Additive Lamphouse, and is only truly useful if the grading system and printer light cuing system are also identical. Laboratories that specialize in archive work can rarely manage these luxuries as the printers are probably of widely differing lamphouses and cueing systems. Nevertheless, a standard is essential as it allows the control operator to know the difference between one printer and another and permits a convertion, even if only approximate, when a film printed on one printer is transferred to another.

Every printer has some form of adjustment for its lamphouse and light source. These come in many forms and could include:

- Lamp voltage control.
- Lamp position in lamphouse.
- Filters.
- Aperture.

Additive lamphouses are fitted with 'trim' which are gross setting controls that move the entire range of 51 printer light valves to different levels and separately control the red, green and blue light valves. With these adjustments it is possible to set the light source to a predetermined light and colour level and with daily printer control tests to maintain the same exposure level.

There are two methods of controlling a printer to a standard value.

12.7.1 Gate photometer

Several modern printers will accept one of the gate photometers on the market mounted at the exposure gate. This allows the light to be read in terms of intensity and colour and adjusted by changing filters or trim settings back to a preset level.

These photometers are of great value when a lamp blows, and are very precise at measuring and restoring intensity levels when dealing with a replacement lamp of the same model. None is very precise in recording colour balance and this is probably because the response of the photocells used in gate photometers is not similar to a colour print material's sensitivity. Nevertheless, these are valuable if expensive instruments, and shorten the trial-and-error testing of new lamps and equipment.

12.7.2 Using a test negative

Printer control follows broadly similar principles to process control except only one step is required to be plotted. A typical printer control strip consists of a single picture frame with a patch of density reading about 0.8.

Several commercially available exposed and processed camera negative rolls are available for colour, but laboratories make their own standard negative on black and white. Some laboratories concerned with film production (rather than archive film restoration) not only make their own but cut a few frames of them into the leader of every negative roll to use them as a standard that is permanently present at every printing. This practice became common throughout the world from the early 1960s and may one day be an important method for archives to identify the source of the film. The laboratory's name is almost always present and the styles of the picture that is usually part of the frame is often unique to a period.

Most standard negatives contain a grey scale and colour patches and a skin tone in the form of a girl's portrait. These were and are called 'lady wedges', or 'lady negs', or were even called by the name of the girl used as the model for the flesh tone element. Kodak Limited, Kodak Pathé, and Eastman Kodak all produced these standards too, and as the negative was an original it had to be remade every year or so using another girl model. This means that there are perhaps hundreds of different standard negatives cut into the front (or back) of production negatives. Laboratories that did not make their own negative used the commercially available ones and in Europe from 1965 to the late 1980s the 'BKSTS Girl' was the commonest. (BKSTS is the British Kinematographic Sound and Television Society.) In the USA Eastman's 'China Girl' predominated. Television companies also made standard negatives as a method of tying together the printer control with the telecine control, and in the UK Thames Television and Rediffusion had characteristic standard negatives. Today there are many less interesting standard negatives with just the grey and colour patches and no picture! Some have sound density check positions.

For each and every printer in the laboratory the density reading from a printed standard negative can be plotted on a running or clothes-line plot. In the case of colour film separate red, green and blue readings are taken and plotted. If the printer has a separate sound gate then some laboratories prepare a clothes-line plot for the reading in the sound track area. Many laboratories dispense with the running plot for printer control and simply keep a log book for each printer. The running plot with show quickly if a lamp is beginning to fluctuate or diminish in brightness which is usually a sign that it is about to expire altogether.

12.7.3 Printer settings for different film stocks

The records needed for a printer are not only to control the fluctuations of the printer lamp but also to define the changes of trim and or filtration needed to allow the various different film stocks and film stock batches to be used interchangeably. Largely because of this complication running plots are not used, but the following procedure adopted instead:

1. Daily a printer control test is printed and processed using one primary material. Most laboratories use a single batch of Eastman Colour Print for all colour printers and one of the Black and White Release print films for black and white printers. The density of the test patch can be plotted on a running plot for each printer.
2. On a regular routine the other film stocks and alternative batches are tested similarly in order to prepare a table of adjustments from the standard in (1) above. Each printer has a notice or chalk board beside it which lists all the possible alternatives and the settings. Additive colour printers usually just require the new trim settings for each alternative stock.

12.7.4 Interpretation and printer control

Exposure is the product of time and light intensity and so a correction to the exposure received in a printer can be carried out by altering the time or the intensity. Colour film printing requires the control of the colour of the light as well.

12.7.5 Time control

With a continuous printer the only way we can alter the time is by altering the speed of the film past the printer gate. Some printers have a speed control, either continuously variable or in discrete steps. If it does not have a speed control then the only way to change the speed is by changing mechanical components such as the motor or drive pulleys. With step printers the time of exposure of each frame is changed by altering the speed or by changing the duration the shutter is open. This last is not a convenient or accurate way of altering exposure. It can be used for gross corrections such as making adjustment for very slow stocks.

12.7.6 Intensity control

The usual method of control is to vary the light intensity. There are three main methods:

1. Changing the light output of the lamp by altering the voltage or current of the lamp. Changing the voltage, which is more common than changing the current (other than on sound lamps which are low voltage high current), will also change the colour of the light from the lamp. The higher the voltage the bluer the light; the lower the voltage the yellower the light. While this is not significant for black and white films a colour correction will have to be made for colour films.
2. Changing the light output by inserting neutral density filters in the light beam. Neutral Density filters vary the light transmitted. They are available in increments of 0.1 with an additional 0.05. A 0.5 is equivalent to 2 printer points (Bell and Howell). Colour filters are also available in red, green, blue, cyan, magenta and yellow and the same values. Any filters introduced into the printer are not normally in image forming light to avoid affecting the image definition.
3. Changing the trims if light valves are fitted. As covered in Chapter 13, the unit of measurement of exposure on a printer is the 'printer point'. A printer point is the smallest increment that we can vary the light on the printer by when printing. In the early days when there were numerous manufacturers of printing machines each manufacturer used a different system to vary the exposure and the amount the exposure varied was also different. Today the printer point has been standardized as the Bell and Howell printer point or the increment produced originally by the Bell and Howell Model C light valve. The precise exposure change for each printer point is 0.025 log *E*. Twelve printer points are equal to one camera stop or a doubling of light.

12 printer points	= $12 \times 0.025 \log E$
	= $0.3 \log E$
the log of 2	= 0.3013, so the exposure change is a factor of 2.

Sometime (rarely) it is necessary to use all three options on the same printer.

12.7.7 Example of practical printer control

The interpretation of printer control data is best demonstrated by an example of the control procedure used in a specialist archive restoration laboratory that has a number of very different printers.

The photographic control of a printer is by means of a test negative strip consisting of a neutral patch with a density of 0.8. This density was chosen as representing the midpoint of a well-exposed negative. When this image is printed onto positive stock the aim is to obtain a density of 1.3. This relates to a position on the sensitometric curve from a negative density of 0.8 onto the print stock.

The density obtained on the positive film will depend on the activity of the process. If the process is off aim then the print density will be equally off aim. A process control strip of the same film stock is processed at the same time as the printer strip and the reading for the positive strip corrected if necessary.

For example, if the process strip is reading 0.05 high at the 1.30 step, 0.05 is subtracted from the reading of the printer strip. If this is not done the correction deduced for the printer will, in part, be due to process variation instead! Laboratory technicians call this 'chasing the process'!

Once the printer strip is corrected for any process variation any other variation will be due to the printer and will need correction. It is wise to be conservative about any corrections, and look for a trend rather than a single aberrant reading. Only if the technician is satisified that an alteration is necessary, should one be made.

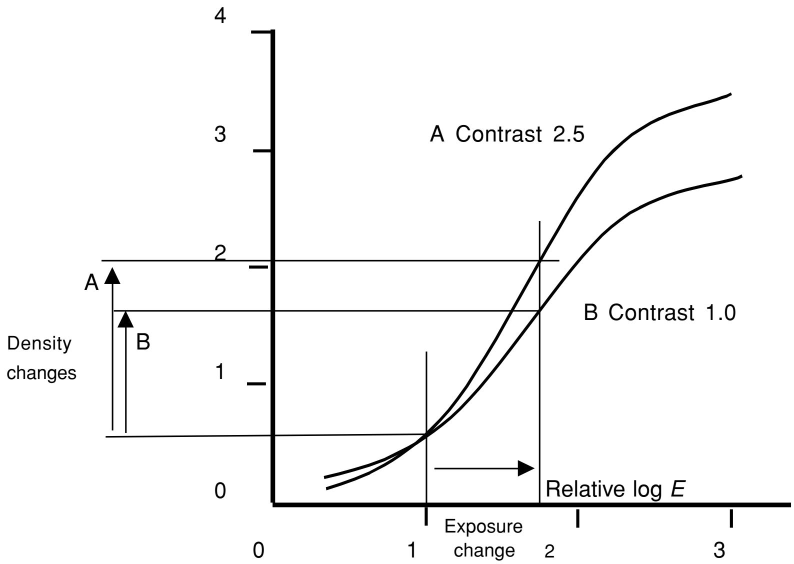


Figure 12.14 Printing corrections. A high contrast film produces a greater density change for the same exposure increase than a lower contrast film

The alteration to the light intensity to make the correction will depend on the contrast of the print stock.

Contrast = cb/ab = 2.60 (for B/W Positive stock)
cb = actual density – aim density = 1.42 – 1.30 = 0.12
ab = log *E* = cb/2.60 = .12/2.60 = 0.046

In order to make the adjustment it is necessary to alter the log exposure by 0.46. The actual density is higher than the aim so the exposure must be reduced.

Adjustment can be acheived by adding a neutral density of 0.05 (the nearest to 0.046). Alternatively, the trims can be reduced by 0.046/0.025 (the log *E* of 1 printer point) – approximately = 2. Alternatively, the lamp voltage can be reduced by 4 volts (an alteration known by previous test to produce this reduction). The choice of which of these techniques to use to reduce the exposure will depend on the printer and what alternatives are possible.

Once calculated, we can apply this correction to all the stocks we use on this particular printer.

12.8 QUALITY CHECKING

The end product of a restoration project is a piece of film – ten reels long or just a few metres. Whatever the length, it has to be suitable for the purpose, and the best visual quality obtainable from that original.

In most cases the film is intended for either optical projection or for video transfer and these two purposes may result in two different results.

The major problem with all archive film conservation and restoration is that today we do not project film using the same projectors and the same light sources onto the same screens as was done in the past. Since much of the oldest film that needs to be preserved is in the last stages of decomposition, the quality obtainable will be quite low, and from this film it is essential to be sure that the result obtained is the best possible from that original.

Thus, the first problem facing a Quality Checker is the definition of 'quality'. The objective in assessing modern film quality is always to acheive a print with good gradation that has the least visible grain possible and is as sharp and has the highest quality sound as the film stocks used will permit. Defects should be at a minimum. To apply that philosophy to a wide range of archival films covering 100 years of film stocks and equipment requires the judgement of Solomon and an understanding of the state of the original starting point from which the restored image has come – qualities that virtually no archive technician possesses.

Many technicians acquire experience in judging the quality of a projected film image, and such staff are important in viewing all the work restored for the archive. They should have regular contact with other laboratories and archives – it is quite easy to adopt a local attitude (for example to a preferred contrast or a print density that suits specific projection equipment) and frequent checking with other parts of the film archive world is essential to prevent isolation.

The grader has the best opportunity to judge whether a particular film restoration could be improved by a different film stock, a change in sensitometry or grading, and the print quality checking technician needs to be in frequent and detailed contact with him or her.

Most experienced archive film technicians know that a result can always be improved on either by spending more time on testing or by a change in equipment or technique. However, economics play an important part in film restoration, and for this reason no original should ever be destroyed, unless the image passes beyond recall, since it may be possible in the future to prepare a far better restoration.

Digital film restoration techniques do exist today that can restore images to almost whatever image is needed, but the today is often quite unacceptable. It does illustrate, however, that conventional film restorations are limited in scope and ability and archive images could eventually be restored again at a far higher level of quality.

12.8.1 Viewing film

Projectors

Projector technology has changed little since 1910, but light sources have. Film made prior to about 1950 would have been seen by carbon arc, after that increasingly by xenon arc. 16 mm film was generally projected by incandescent tungsten until the mid 1960s and then increasingly by tungsten–halogen. Modern projectors are brighter – the standard brightness of a screen image today is 9–14 foot lamberts but most modern cinema and surely all laboratory screens are generally brighter than 18 foot lamberts

The best projection system for assessing quality of a restoration is a cinema projector producing the standard light output required of a commercial theatre, since that is where a film will be seen today.

High speed viewing machines

High speed viewers such as the Hollywood Film Co. High Speed Projector (operating at 150 fr/sec, 500 ft/min or six times 'real' time) have been used in laboratories for a generation for checking the quality of release prints, but are not used for checking archive film since the projection speed is too high to detect defects.

Editing tables

Conventional editing tables (Steenbeck, Moviola etc.) are frequently used for all forms of viewing of both original archive film and restorations. Some machines are modified to handle shrunken film. Most editing tables have tungsten–halogen light sources with removable filters to convert the light to a colour temperature close to xenon, and these are suitable for quality checking, provided it is accepted that an editing table will always be second best to a cinema screen. It is too small and the angle of the image subtended by the eye is too restricted to be comparable, and the surroundings therefore play a large part in the judgement of an image.

Rewind table with a light source

The flat bed rewind table with an illuminated opal glass screen is probably more accurate than is realized, provided the room is darkened, a large mounted magnifier is used to view the frame, and the light source is the same colour temperature as a projector. Several manufacturers make special fluorescent tubes for this purpose with a colour temperature of 5,500°K, which is ideal for colour grading.

(*a*)

(*b*)

Figure 12.15 (a) A modified 35 mm Steenbeck editing table used for viewing archive film. (b) A 35 mm Lipsner-Smith Vedette viewer used for checking prints

13

Printing

13.1 INTRODUCTION

Motion picture film equipment for printing consists of a means of transporting a (negative or positive) processed film and an unexposed film (positive or negative), past an illuminated aperture or 'gate'. The exposure to light, whether through a lens or by contact, must be varied to print the image of the original onto the print film at a desired printing exposure.

This definition disguises the great range of technology that covers this subject. The earliest printers were contact printers whereby the original camera film after processing and the unexposed film were driven together by two sprocket rollers, one just before and the other just after the gate. The transport was continuous, or intermittent and frame by frame, and the image of the original was contact printed onto the unexposed film. Step printers which exposed the frames one at a time may have been the most commonly used for the first 40 years of the cinema, but continuous contact printers were more flexible as they could handle a wider range of frame positions. There were no standards for frame line position until the late 1920s.

Within a few years of the beginnings of cinema a wide range of different printers were in use and modern printers are sophisticated developments of the principles that were established at the turn of the century.

Printers can be divided into two types to indicate the way in which the raw stock is exposed, either in **contact** with the original, or by **optical** projection, in which an image of the original is formed on the unexposed film by a copying lens. A further division of types is made according to how the film moves: **continuous** movement, where both original and raw stock are moved at constant speed, or **intermittent** where the two strips are moved one frame at a time and held stationary for the period of exposure (also called **step**). Printers also come as **dry** or **wet** depending on whether the original film, when being exposed in the printer gate, is in a liquid or is dry.

13.2 CONTACT PRINTERS

13.2.1 Intermittent or step contact printers

In an intermittent contact printer (see Figure 13.1), the original (O) and the unexposed (R) film are brought together, emulsion to

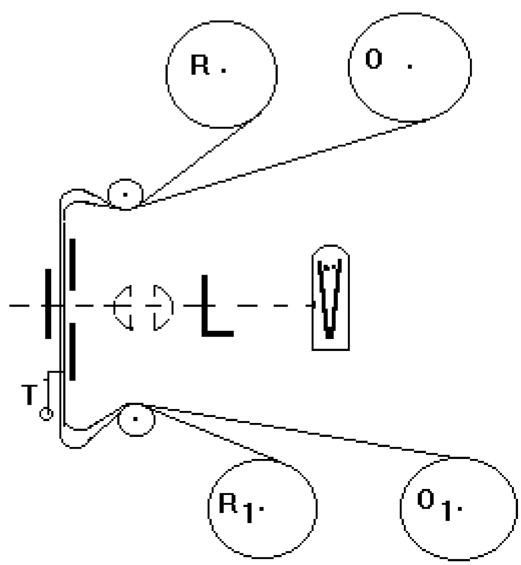


Figure 13.1 Optical and film path of a step contact printer

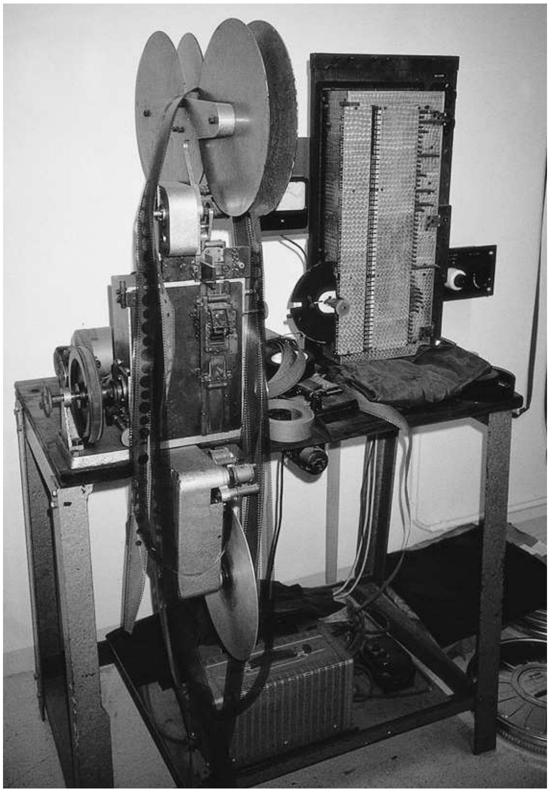


Figure 13.2 A step contact printer of the late 1920s made by Debrie in France (Cinemathèque Royale de Belgique, Brussels)

emulsion, onto a continuously rotating sprocket wheel. After forming a loop, they pass in close contact (to ensure good sharpness) through a tensioned gate (T) in which an aperture, slightly larger than the original picture area, admits light from the source, via a condenser lens. After forming a second loop below the gate the films pass under a take-up sprocket and then separate, the original and the exposed raw stock being spooled up on separate reels.

The loops are formed in the paths of each film, both before and after the gate, to absorb film from and to the sprockets during the stationary period of the intermittent motion.

The two films are both pulled intermittently and synchronously through the gate by a claw mechanism T. Whilst the films are being moved forward the rotating shutter S obscures light from the printing aperture. Immediately the claw has completed the forward stroke, the open section of the shutter reveals the printing aperture and light is again passed to the films.

In certain precision step printers, the two films are also very exactly positioned in the aperture by closely fitting register pins which engage in chosen perforation holes of the two films in the gate.

The printing speed of such a machine is rather slow, of the order of about 50 feet

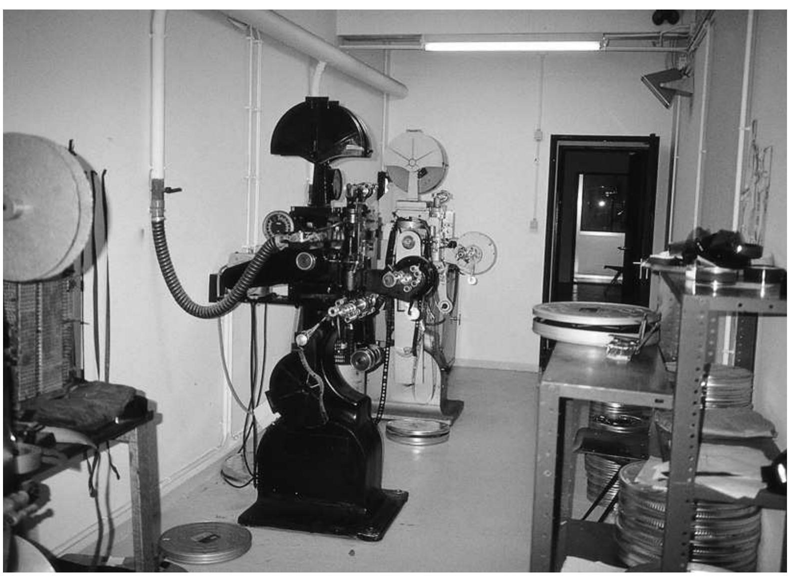


Figure 13.3 A pair of 35 mm Debrie Matipo step contact printers, 1935–1950. The workhorse of the laboratories in that period (Cinemathèque Royale de Belgique, Brussels)

Figure 13.4 A 35 mm Neilson–Hordell step contact register printer, with a 1970s additive lamphouse (Soho Images, London)

(15 m) per minute with good picture steadiness and repeatable exposure. Because of the slow speed, such printers are able to take damaged and shrunken material up to a certain limit.

The Matipo printer was made by Debrie, of Paris, for 40 years and many specialist archive laboratories still keep them running. It is the workhorse printer of many archives and is a 'precision' printer with a register pin to ensure that the film is firmly and repeatedly held in the same position for each frame. This pin is often removed to enable shrunken film to be handled without damage.

The Arri step printer, from Arnold and Richter of Munich, was a similar printer that was made for many years.

13.2.2 Continuous contact printer

The layout of a simple continuous contact printing system is seen in the illustration. In this machine both original and raw stock are fed from the upper supply sprocket, via a series of rollers, to the main central sprocket which carries them in close contact past the printing aperture. Good contact between the two films is obtained by holding them to a curved path at the printing aperture, first by the tension derived from the weighted idler (i.e. free running) rollers and, secondly, by pressure from the polished steel shoe. The

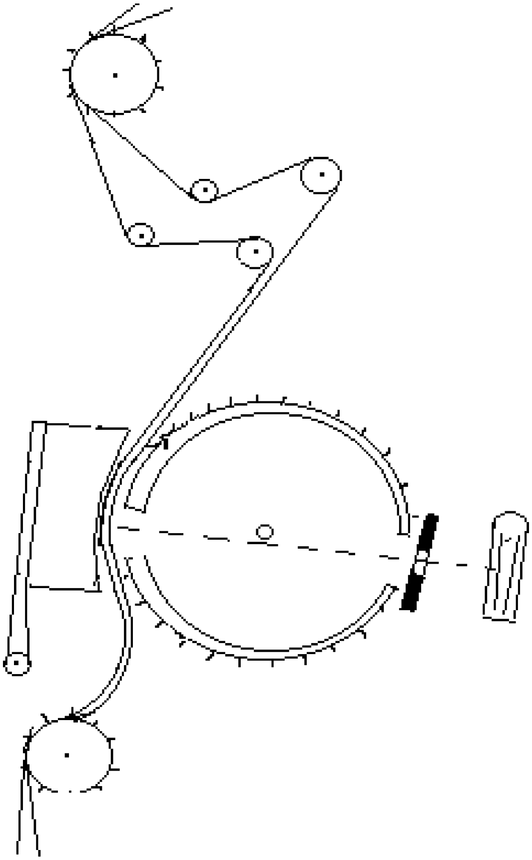


Figure 13.5 Optical and film path of a continuous rotary contact printer

main sprocket is enclosed so that light only reaches the original and raw stock film combination at the printing aperture and, in this arrangement, from the lamp via a suitable condenser lens system.

Figure 13.6 shows a printer with a very curved gate that by virtue of that curve tensions the two films and holds them in good contact. This is frequently called a rotary contact printer. Good examples of these are everywhere in the film industry today, as almost all cinema prints are made on these machines. Examples of these printers are the Bell and Howell printers, made in Chicago, Models J, D and C. The Model C is still being made today by BHP Inc. Many other companies made these types of printer – Union, Lynes, Hollywood Film Co., Carter, Peterson, Arri, Debrie and so on.

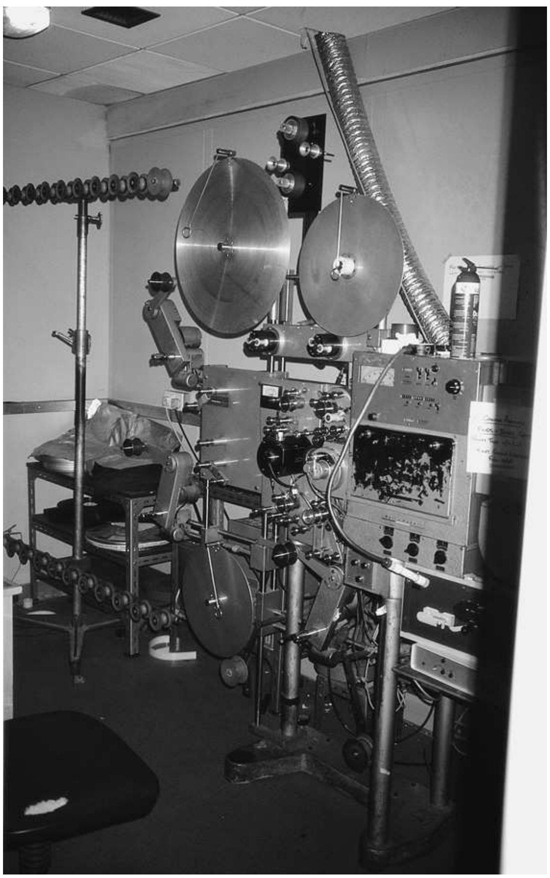


Figure 13.6 A 35 mm Bell and Howell Model C rotary contact printer, with additive lamphouse, about 1969. This was the standard printer from 1965 to 1990 (Soho Images, London)

Rotary printers are generally high speed printers, operating at speeds from 60 ft/min to over 1000 ft/min. No matter what the speed of operation, absolutely uniform continuous movement is essential to avoid irregular exposure, and the contact between the two films must be consistent and intimate during the whole exposure period.

Most contact printers are sprocket driven like all other printers, but the BHP Modular Printer is effectively friction or 'capstan' driven with one sprocket wheel at the film gate to fix the location of the two print stocks only at this point.

Some continuous contact printers of almost exactly the same design as those used in the 1890s were made until the 1950s. These have the two sprocket drive rollers and a flat or only slightly curved gate and are sometimes called **flatbed** printers. In England the companies Vinten and Lawley both made flatbed printers, which were the cheapest and easiest to make. Throughout the world these printers have been copied many times and local versions made by hand can be seen from Brazil to India.

13.2.3 Film slip

When two identical films are driven by the same sprocket over a curved surface as with a rotary printer, the outer layer moves on a circumference of a slightly larger radius than the inner and some slip between the two is bound to occur. If this slip or relative movement of the two occurs during exposure there is a loss of definition of the printed image. Slip occurs more obviously the smaller the radius of the curve and slip is less obvious

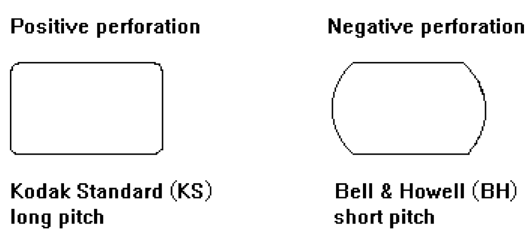


Figure 13.7 Perforations

if the film is flat in the gate, thus 'flat bed' printers such as those used until the 1950s, are still used by some laboratories. Flat bed printers are particularly useful, but slow, for badly damaged and shrunken film. To avoid slip and consequent loss of image definition, it became the practice to manufacture negative raw stock (the inner film on a rotary gate) with a short perforation pitch (which became known as 'Bell and Howell' or BH). Print raw stock (the outer film) was made with the Kodak Standard pitch (KS, or 'long pitch').

The dimension of the exposure aperture of the continuous contact printer is made as small as possible so that the distance over which the two films must stay in contact is at a minimum. The gate aperture need only be a narrow slit.

Serious problems are encountered when printing shrunken material. The shrinkage of the original makes it even smaller than the design aim and causes inevitable slippage between the original and the duplicating stock. This is seen as a loss in definition and is sometimes mistakenly assumed to be poor definition in the original image. A further problem in handling shrunken film is that the sprocket drive, designed for longer pitch film can damage the perforation, eventually, in severe cases, ripping the perforations and the film.

Flat bed printers can handle shrunken film more easily than rotary printers as the curvature of the gate is much less, especially if the film is driven by only one sprocket roller instead of the normal two.

13.3 OPTICAL PRINTERS

13.3.1 Intermittent or step optical printers

Optical printing is a technique where the original and the raw stock films are not in contact with each other, but are separated by a lens system.

The image of the original is focused onto the raw stock film printing aperture by a lens system between the two heads. In essence an optical printer can be regarded as a projector mechanism projecting an image of the original onto the print film which is transported by a

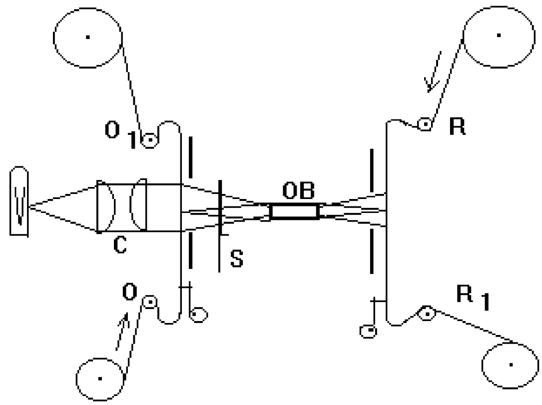


Figure 13.8 Optical and film path of a step optical printer

camera mechanism. In some optical printers it is easy to see the two separate parts which are often call the 'projector' and the 'camera' mechanisms.

An optical printer is shown schematically in Figure 13.8.

Light from the source is focused by a condenser lens (C) on to the objective lens (OB). The original image is focused on to the raw stock by the objective lens. The shutter (S) interrupts the light beam each time the two films move forward one frame. The original and raw stock are moved in **opposite** directions by the link claws and there are also the usual feed sprockets and hold-back sprockets.

A printer designed on this principle makes it possible to produce prints of equal size (1:1), and of a different size from the original simply by altering the distance between the lens and the camera mechanism and focusing by adjusting the projector/lens distance. Early optical printers were designed to make a print of exactly the same size as the negative (i.e. 1:1). However, within a few years of the new century optical printers could make a larger or smaller print to accommodate changes of gauge and format and were often used to make selective enlargements, to crop out unwanted detail, for example. A good example is to be found in the British Pathé collection where there are two versions of a short film using 'trick' photography (double exposure in the camera) made about 1905.

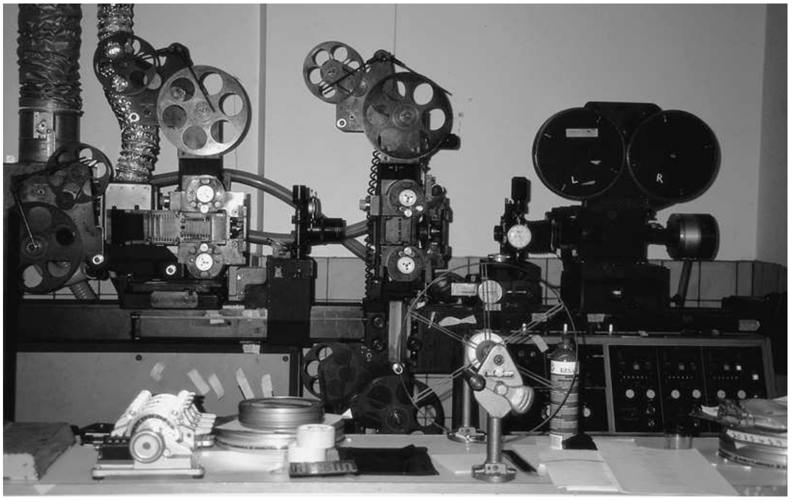


Figure 13.9 An Oxberry step optical printer, about 1965, for both 35 mm or 16 mm use. Originally for blow-up, reduction printing and special effects, this printer is fitted with a 1985 Neilson–Hordell wet gate and a reduced pitch pull down for shrunken film (Soho Images, London)

Figure 13.10 A Debrie TAI Printer, 35 mm step optical with a total immersion wet gate, additive lamphouse and variable pitch pull down for shrunken film (Cinemathèque Royale de Belgique, Brussels)

One is from the original negative at 1:1, the other is considerably enlarged to concentrate on the action and cut out the background, to improve the dramatic effect.

By the late 1930s the optical printer was widely used to **reduction print**, that is, to make, for example, duplicate negatives or prints on 16 mm from 35 mm originals. In the 1960s optical printers began to be used extensively to **blow up**, for example to make 35 mm prints from 16 mm originals.

Some of the optical printers made were restricted in their ability to alter formats and magnifications, but those that were mounted on an 'optical bench' that could move their various parts independently are extremely flexible and can 'do anything'.

This type of printer offers several advantages, but also some disadvantages.

Advantages are:

- possibility of setting the claw stroke for the original film differently from that for the raw stock, allowing badly shrunken originals to be handled;
- possibility of small reduction or enlargement of the original image to make minor adjustments of magnification;

- possibility of reframing horizontally and vertically;
- possibility of copying films with a high degree of damage, because the original is in a separate gate to that containing the raw stock.

Disadvantages are:
- increasing contrast;
- increasing the apparent graininess of the final image;
- more dirt, dust and scratches are revealed on the original;
- difficult to copy the informative marks on the margins of the original;
- possible introduction of a certain amount of flare.

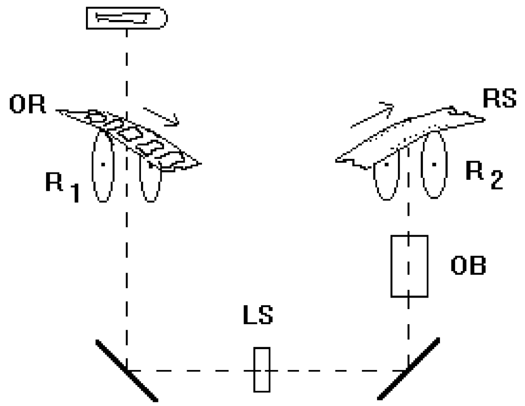


Figure 13.11 Optical and film path of a continuous optical printer

Some of the older optical printers do suffer from quite serious **flare**. This is the scattering of light within the lens and mechanism that finally falls on the film as non-image forming exposure reducing the contrast. The increases in contrast and the increases in apparent graininess are largely due to poor lens design and modern optical printers have overcome most or all of these objections.

This type of printer is very suitable for archival use, especially when equipped for wet printing. Although many manufacturers made optical printers, only the best and the most flexible are really suitable for archive use. However, just one of these printers can carry out all the operations required, and suffer principally from the shortcoming that they are generally, with the exception of the Debrie TAI, rather slow. Other examples are from Oxberry (USA), Neilson–Hordell (UK), Seiki-BHP (USA/Japan), and Acme (USA).

13.3.2 Continuous optical printers

As with optical step printers, the original and the raw stock films are not in contact with each other, but run continuously and synchronously at a constant speed in an opposite direction.

Figure 13.11 shows the principle on which the Sigma continuous optical wet printer was built. The constant light beam from the source projects the original image (OR), reflected by two mirrors or prisms and passing through the light change system (LS) and the objective (OB), onto the raw stock film (RS). This type of printer has the same disadvantages and advantages as the optical step printer when specially equipped.

For archive work, the Sigma printer made solely for the National Film and Television Archive laboratory at Berkhamsted, UK, is the only example of this printing principle used for archive printing. However, other printers exist and used to exist using this principle. The largest were those made in the 1970s to print from 16 mm or 35 mm negatives onto 2, 4 or even 8 rows of Super 8 on 16 mm, 35 mm or 70 mm film, printing all the rows simultaneously via a beam splitter optical system. Most of the product was either educational films or adult movies, neither of which seem to be collected in archives much yet!

13.3.3 Optical sound printing

Whichever type of printing machine (step or continuous, contact or optical) is used, the optical sound track printing is always carried out on a separate rotary contact gate. This is not a problem on a rotary contact printer as a second gate can be placed after the image gate and at this point the separate sound negative replaces the image negative.

On intermittent printers sound gates (often called **sound heads**) are positioned some distance from the image gate after the loop, by which time the film movement is continuous and smooth.

The sound gate is a narrow slot no wider than the width of the sound track. Many optical printers have no sound heads and **tracking**, as the process of printing an optical sound track onto a print has to be done on a separate printer as a separate printing run. Rotary contact printers are mostly used for this. The biggest problem with this procedure is the synchronizing of the picture image on one printer with the sound on another. This procedure was commonplace in the early days of optical sound, and in the early 1930s several printers were available on the market simply to print the sound tracks after the picture had been exposed. Only later were printers fitted with sound heads in the same film path.

13.4 OTHER PRINTING MACHINES

Throughout the past century some truly amazing printing machines have been built, and it requires a separate publication to review them properly. From an archives point of view, only a few of the more complex ones have any relevance. Generally, they were designed to produce prints more quickly or more cheaply than other printers, but the following types, some old and some modern, have had a significant influence on film production.

13.4.1 Cascade printers

Cascade printers comprised a sequence of rotary contact printing heads arranged on a single negative path. Each head (up to 10) printed the negative onto separate print stock rolls. These printers were extensively used for printing multiple copies of newsreels.

13.4.2 Panel printers

Panel printers are rotary contact printers printing first from the head of the film and then printing in contact onto another roll of film in the reverse as the negative is rewound, speeding up production for multiple copies. These printers were extensively used from about 1970 onwards.

13.4.3 Loop printers

A loop printer is usually a unidirectional rotary contact printer, like a Bell and Howell Mod C, printing two loops of film, one the image negative, the other the sound negative, continuously to produce multiple copies of a short film. The loops are housed in 'loop cabinets' built very much like a processing machine drying cabinet. Printers of this type are especially used for TV commercials.

Numerous other specialist printers exist: for high outputs, for multiple copies, for specialist printing procedures such as for Dufay colour film, for Technicolor, for Cinecolor, for 'duplitized' film exposed on both sides of the film base and so on. Details of these are given in such publications listed in the bibliography, notably those of Wheeler (1969) and Cornwell-Clyne (1951) (for colour films).

13.5 WET PRINTING

13.5.1 Principles

More effective than the scratch treatments normally used and mentioned in Chapter 11, the technique of wet printing can provide clean copies from originals scratched on the base and to a lesser degree on the emulsion.

The effect of a scratch is shown in Figure 13.13(a). Light transmitted by the film is

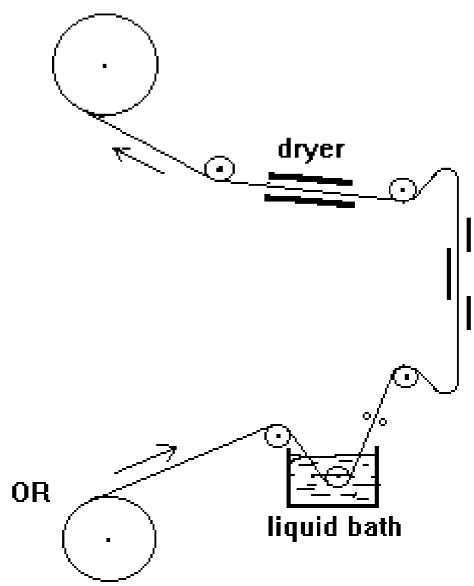
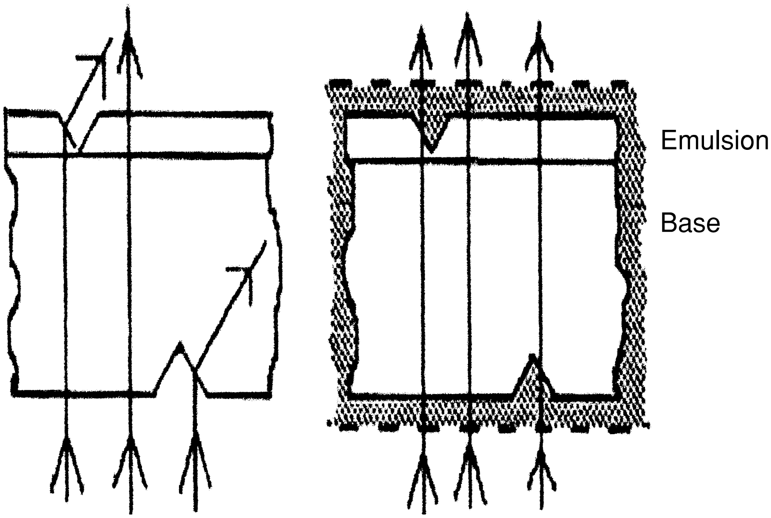


Figure 13.12 The simplest form of wet gate printing – film dips through the liquid before entering the exposure gate



(*a*) (*b*)

Figure 13.13 (*a*) A scratch on the base of a film deflects the light path and this is seen as a black line. (*b*) The solvent is approximately the same refractive index as the film and so scratches do not cause a deflecting of the light path through the film

refracted and scattered by surface scratches and thus the scratch is seen as a dark line. If the film surface is coated with the liquid of the same (or almost the same) refractive index as the film (Figure 13.13(b), dotted lines), light passes through it undeviated and a dark line is not seen.

Wet printing is based upon this phenomenon and depends for its success on the selection of a liquid with two qualities: first it must have the same or nearly the same refractive index as the film base (cellulose acetate has a refractive index of 1.490); and secondly, it must not contain water so that the liquid will not be absorbed by the film emulsion during printing, primarily so that the liquid can be dried off quickly before the film is wound up.

Trichloroethylene (index 1.478) has the nearest optical properties to those of the film base and emulsion. However, this liquid is too volatile for pre-wet printing so that the evaporation from the surface of the film, before reaching the exposure aperture, is too high. Trichloroethylene is going to be proscribed in most countries because of its toxicity. It also removes the plasticiser from the film base and after several printing passes makes film brittle. Perchloroethylene (index 1.504) is less volatile and is therefore preferred.

There are three basic methods of wet printing:

1. Pre-wet printing
2. Wet gate printing
3. Total immersion or aquarium gates

13.5.2 Pre-wet printing

In pre-wet printing, a thin coating of the liquid is applied onto the film just before the printing aperture. This can be done by passing the original through a small bath of the liquid or by applying the liquid on the original with velvet or felt pad applicators, or by a liquid spray on the original. The Seiki printer uses this method which is quite difficult to set up properly and critical to maintain, but is very suited to high printing speeds of up to 50 fr/sec (nearly 200 ft/min).

13.5.3 Wet gate printing

In a wet gate, the original passes between two optical pieces of glass, between which the liquid circulates. The technique was perfected by a Dr Ott and for many years any wet printing gate was known as an **Ott gate** and used almost exclusively for optical step printers.

The greatest problem with a wet gate of this type is that the liquid is at risk of leaking out where the film passes in and out of the gate, as no seals are ever fully leak-proof. As the film passes through the seals it is inevitable that air bubbles will be pulled in and trapped in the

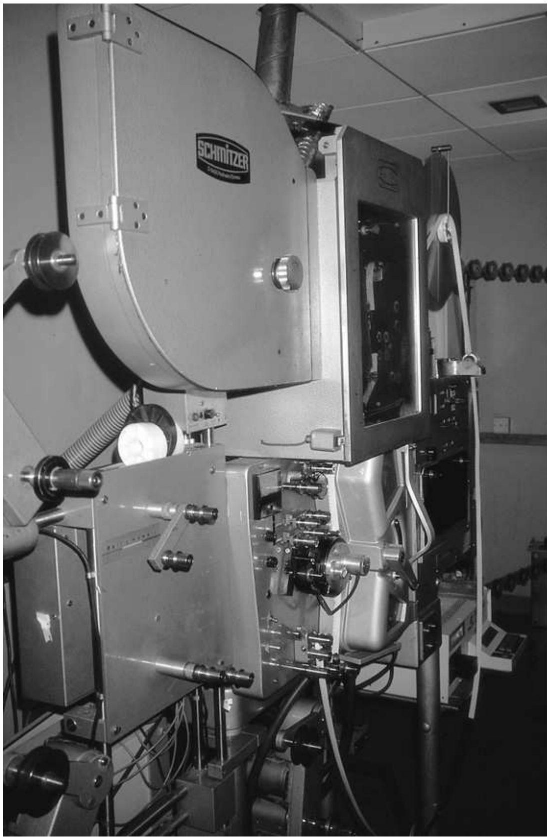


Figure 13.14 A Schmitzer wet gate head, about 1990, fitted to a 1970s 35 mm Bell and Howell Model C rotary contact printer (Soho Images, London)

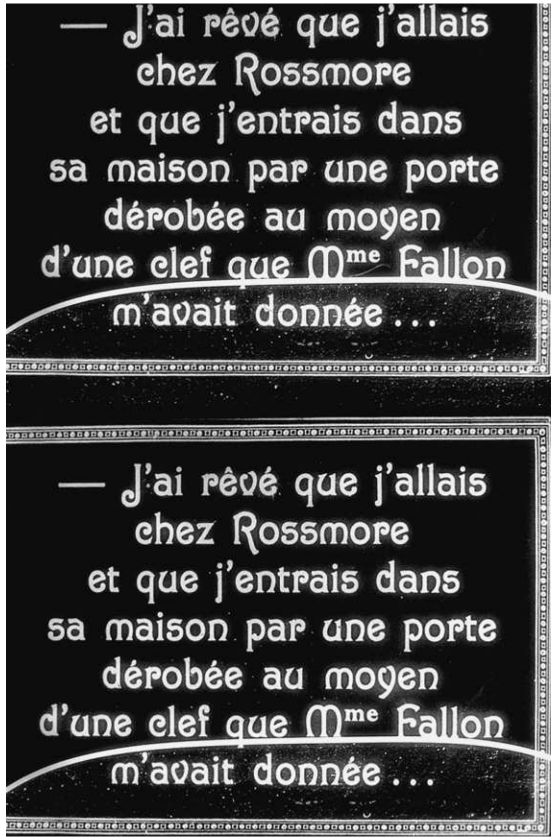


Figure 13.15 The effect of wet gate printing. The top section of the frame is coated with perchlorethylene which has a similar refractive index to the film base. The marks and scratches on the film base are minimized

gate. If this happens the bubbles can be seen as images on the print. The earliest gates all suffered from this problem which was eventually overcome by pumping the fluid round a circuit that included the gate, a reservoir of fluid, and a filter (to trap dust and dirt). The pumping action pressurized the fluid which prevented air bubbles from entering. The early Ott gates all leaked, especially when a splice went through the seals; indeed the early wet gates were called 'splash gates' in some British laboratories!

Modern wet gates as used on Oxberry, Debrie and Neilson–Hordell, and the Peterson, Schmitzer and other modern wet gates, are very different and the improvements are largely due to the choice of modern materials for the seals and pipes and pumps. Viton and Neoprene have revolutionized wet printing today.

Ott type gates all suffer from the problems of bubbles of air trapped in the gate, especially at the start of a printing run, and these are overcome by pumping the fluid through the gate and through a liquid chamber that can trap or eliminate bubbles. The Ott type wet gate can be applied more easily to optical printing than to contact printing.

Archival shrunken films are difficult to use on Ott gates, because the presence of the liquid and two tight seals does not easily allow the slip between the two films. This problem was overcome in the past by the use of lubricants (simple paraffin wax) mixed into the liquid or by using a greater amount of the liquid itself as a lubricant and pre-wetting the films. However other, better methods exist today.

13.5.4 Total immersion or aquarium gates

In this system the printing head with the original film (in the case of an optical printer) or the two films (in the case of a rotary contact printer) is completely immersed in an aquarium containing the recirculated liquid. Generally the printing head is placed horizontally, so that the film path is side to side, rather than top to bottom as in most 'dry' printers.

The Debrie TAI is an example of an optical printer using this system and BHP, Hollywood Film, Peterson, and Debrie all make total immersion gate rotary contact printers.

After printing, the original film passes through a drying chamber or air channel (see Figure 13.12) to dry the film before it is wound on to the take-up spool.

All of the liquids used for wet printing are toxic, therefore a good and sufficient exhaust and ventilation system should be provided. As the evaporation fumes of these liquids are heavier than air, there should be an exhaust system at floor level. Perchloroethylene is today almost the only wet gate liquid in use.

13.6 PRINTING SHRUNKEN FILM

13.6.1 Printer requirements

Film shrunk by more than about 0.6% cannot be safely printed on most normal printers without some modifications, otherwise film slippage occurs. A wide range of modifications exist falling into one of the following categories.

1. Shorter than normal pitch sprocket drive rollers can be fitted in place of normal rollers. This might require 25 new rollers in the case of a modern rotary contact Peterson immersion gate printer. This would handle a narrow range of shrinkage, approximately 0.4% to 0.9%. Another set of 25 would be required for each range of shrinkage.
2. Worn down or filed down teeth on sprocket drive rollers or pull down claw mechanisms (e.g. on old printers) work better on shrunken film (and may not actually fit new film!).
3. Replacing the pull down claw mechanism of a step printer (optical or contact) with a special short pull down (e.g. Oxberry) or a variable pull down mechanism (Debrie TAI) is an approach for optical printers.
4. Register pins on step printers can be filed down or removed so that the pin will not attempt to engage in a position where the perforation is not quite aligned.
5. Some printers are sufficiently imprecise that they can handle a wide range of film pitches. Old flat bed contact printer falls into this category.

A range of printers are used for printing archive film in laboratories attached to archives and also in commercial laboratories that specialize in archive film restoration. Further details may be found in Chapter 27.

13.6.2 Inferences and comment

1. In Table 13.1 the output column represents the output in **feet per minute** (fpm), or in **frames per second** (fps) and this refers to the most commonly used speeds with shrunken film.
2. The maximum shrinkage possible column is as reported by the organization and has not been checked. It is inevitable that one archive may accept a result that would be unacceptable to another. Many of the continuous rotary printers shown in Table 13.1 probably exhibit slippage of the image to a greater or lesser extent.
3. The best quality is theoretically achieved only by variable pitch optical printers using precision register pins, claws and sprockets which match the sprocket holes and pitch of the shrunken film. The image is then **enlarged** on the print material to be the same size as the original frame before it shrunk. The only printers that can **completely** achieve this are still to be built! The nearest are optical printers with short pitch movements that match the short pitch of the shrunken film. The Oxberry, Research Products and Neilson–Hordell come close to this but are slow. The Sigma (continuous optical) has a reputation for being awkward to handle and difficult to set up, but only two were made. The Debrie TAI (step optical) fitted with a variable pull down is capable of 25 fps and is undoubtedly the best machine for shrunken film. These last

two are the only printers to have been manufactured specifically to handle shrunken nitrate film (1996).

4. Modifications to normal printers include:
   (a) interchangeable gates fitted with short pitch sprockets and/or short pull downs;
   (b) removal of register pins to allow a variation in film position in the gate;
   (c) filing of register pins, claws, and/or sprockets to allow a variation in pitch to be accommodated by a variation in film position in the gate;
   (d) reduction of the wrap around on rotary contact printers (flat gates are always preferable to curved gates if the pitch is short).

   Many archive printers throughout the world simply rely on filed down or worn mechanisms to allow shrunken film to be transported and printed.
5. The only technique reported for assisting short pitch film through standard continuous contact printing gates is pre-waxing to allow the film to slip. Theoretically this could result in low sharpness, as it encourages the films to slip against each other in the exposure gate.
6. Most step printers are slower than the best continuous contact printers. Step printers give steadier pictures than continuous contact printers in general (but this may not be significant in already unsteady archive film).
7. Wet gate prints are unquestionably essential for most archive film to minimize negative scratches, but the Schmitzer, Ott or any gate with rubber or plastic seals touching the film risks catching the edges of old splices and breaking the film. The slow Oxberry just about manages to cope with poor splices. Only 'aquarium' gates, in which the entire head is immersed in the wet gate fluid and the film enters and leaves the liquid through its surface can be used safely at speeds over about 5fps.
8. The fastest printers used for shrunken film are as follows:

   The **Debrie Matipo** – now only available second hand – a step contact, dry printer, is capable of handling the worst material at speeds up to 50 ft/min. It needs some modifications that can be done by a good laboratory engineer (e.g. removal of register pin/s, shortening or filing edges of pin, and shortening and/or filing down claw edges). The disadvantages are that it is not possible to convert to 'wet gate' and that modern grading techniques (using analysers and punch tape or frame count cueing) are not easily possible without fitting an entirely new lamphouse. Similarly, colour grading is not economic without an additive lamphouse.

   For all these limitations, the Matipo is still the workhorse for many archives and is probably the only European printer to be seen in the USA because of this.

   Modified rotary contact printers with or without wet gates. The Bell and Howell Model C, the Carter and the Peterson are all unidirectional printers used by labs and archives with modified gates and/or sprocket drives. Most rely on 'worn down' sprockets, which may make them unsuitable for modern work. Some Model Cs have replaced sprockets and rotary gates with mechanisms with shorter pitches. This makes them very suitable for a range of film shrinkage that has to be selected prior to the modification but it is not easy to change from one range to another. The Schmitzer wet gate attachment combined with a short pitch mechanism is probably a very fast and practical solution but great attention is needed to old splices.

   Peterson have built completely interchangeable printing units for their unidirectional aquarium gate printer. It is said to be easy to change back to standard or to another range of shrinkage.

   The Bell and Howell Modular Printer with its aquarium gate has only a single sprocket roller (at the gate itself) and can be used for shrunken film, especially if the film is not too seriously shrunken. This model is theoretically the simplest and easiest to change sprocket drive. The transport is very smooth, which subjectively disguises slippage at extreme shrinkages, trading off some sharpness for steadiness.
9. There are many other printers that are capable of quite high speeds with shrunken film, but all these are flat bed contact printers of old design. The problem with these (Vinten, early Bell and Howells,

Lawley, Acme and Union amongst others) is that they are now museum pieces, their printer lights are dim and the grading and the cueing systems they use are awkward, slow and unfamiliar to modern graders. Several laboratories report that they have printers like these that are used to make copy negatives of shrunken material where grading was not needed. In theory, a modern light valve lamphouse could be fitted to these old printers but this does not seem to have been done.

10. High speeds can often mean higher tensions and therefore more breaks at joins, so all high speed printers need additional time spent before printing, checking, reinforcing or remaking old joins.
11. The Sigma printers used at NFTA are the only two ever made and it has taken some time to overcome the problems of prototype technology.
12. Given a slow speed and the right choice of drive, shrinkage of up to 5% can be printed. However, by the time most nitrate has shrunk to this extent the base has already broken down. The vast majority of all archive nitrate film shrinkage is between 0.8% and 1.8%. This is beyond the method of waxing on a low curvature rotary contact printer (like a Peterson) and yet to use a slow step optical printer like an Oxberry is often uneconomic. Debrie clearly designed their TAI to fit this requirement, but it is expensive.

13.7 PRINTING IN PRACTICE

13.7.1 Principles

In order to obtain a print that answers to the requirements of the customer or gives a faithful representation of the original copy or scene, the printed material has to be corrected scene by scene, in other words has to be **graded.** The estimation of the printing conditions needed to achieve this acceptable result is called **grading** in English (but **timing** in the USA).

All camera original film has been exposed to varying light levels which, however the camera operator attempts to control the camera exposure, results in variations in density from scene to scene.

Colour film has another dimension of variation in addition to that of exposure level, as the illumination of the original scene varies in terms of the colour of the light. Light varies in its colour composition. Daylight has a far larger proportion of blue light than light from an incandescent electric light bulb. Daylight, too, is not constant in its colour composition and the light of a sunny day contains more red light than daylight on an overcast day. A colour negative therefore has variations in the proportion of red, green and blue information about the scene that depends on the lighting as well as the subject colours.

In order to produce an acceptable visual result on printing, some or all of this variation must be reduced to produce a subjective result that is acceptable from scene to scene.

13.7.2 Printer lights

These are the printing conditions needed to produce a graded print. Printer lights define the exposure required for the print, and in the case of colour also refers to the filtration or other means of defining the colour of the printing light.

To ensure that, during printing, the printer lights required for each scene change at the right place (i.e. at the start of each scene), a signal, called a **cue**, is required to indicate that a change is required.

The print films used in the early days of motion pictures were slow speed and blue-sensitive and quite bright safelights were used. The Kodak OB Safelight Filter over a 60 watt bulb was so bright that the operator could easily read instructions and operate quite precise dials and levers. As film became more sensitive and especially as colour arrived, either no safelight or only a very dim brown light could be used. In consequence, printing had to change to rely on equipment that could be pre-programmed to provide the cue and the new printer light in the dark.

Over the years very many different cueing and light change methods have been invented. The three main and most used cueing methods are those that require some sort of physical marks or signals on the film that indicate when a change in printer light should occur and methods that count the number of frames from a start point to the change point. This last system is known as **frame count cueing** (or **FCC**).

13.8 CUEING METHODS

13.8.1 Debrie charts or 'Pilots'

This system, unique to Debrie printers, consists in a film band that runs synchronously with the film being printed but at 1/8 of the speed of the original. A hole in the film band marks the place where the light change takes place and triggers the light change mechanism to operate.

This method can be used on several Debrie Matipo contact and optical printers. It can be very useful when the original should not be notched or when the original is damaged and notching is impossible.

13.8.2 Lawley clips

The light change signal used on Lawley printers for 30 years throughout the English speaking world is provided by small metallic clips inserted between two perforations of the negative. The disadvantages of this method were that there was a risk of perforation damage in the original and also there was a lot of intensive preparation work. This method has not been used for many years. Many archives and film collections have negatives with these clips and to ensure the safety of the film and also of another printer they have to be removed before the film can be printed. Removing Lawley clips can be a tedious and risky exercise as the film can be damaged around the perforations during the removal. Lawley made a small hand device for the purpose, which is hardly seen anymore. In any case the device was not as quick or as safe (to the film) as an experienced operator with a pen knife!

13.8.3 Notches

A widely used cueing system was provided by a notch cut into the edge of the film. The notch varied in length, from a frame to several frames, depending on the different manufacturer's system, was about 3 mm deep, and did not reach the perforations.

In this method the grader makes a notch on the edge of the original at the point when a light change is required, or, in some systems a fixed number of frames before or after the scene change.

The notch activates the light change mechanism on the printer usually by the action of a lightly sprung roller running on the edge of the film attached to a micro-switch. A disadvantage of this method is that the original film is cut on the edge, and in some ways damages or weakens the film. This method cannot be used when there are damaged perforations in the original and has its greatest benefit when a negative is being reprinted on the same type of printer that was used originally and the notches are already in place.

The two major systems were devised by Debrie in France and Bell and Howell in the USA, but other notch systems, quite obviously based on these, were used for locally made printers in England, India, the old USSR and almost certainly elsewhere. The difference between the Debrie method and the Bell and Howell method consists only in a different

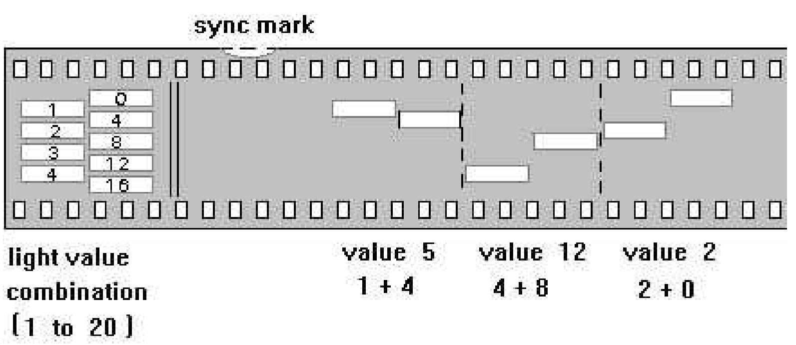


Figure 13.16 Debrie resistance printer light control bands

placement of the notches. The Debrie notches are placed on the scene change and the B&H notches are placed six frames after the scene change in 35 mm.

Some printing machines are adapted for the two methods. The Debrie position is the weakest as it positioned over the splice on a joined negative, and where this is found great care is needed to see that there are no edges to the splice that are standing out. The Bell and Howell notch presents no problems on other printers provided it is undamaged.

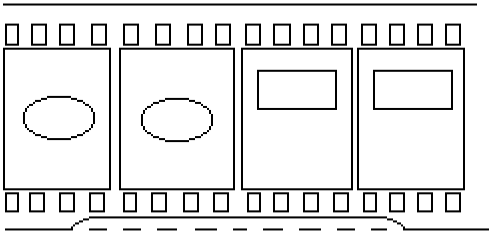


Figure 13.17 Debrie scene change notch at the scene change splice

13.8.4 RF cueing (radio frequency cueing)

RF cues are self-adhesive metal foil tabs stuck on the film between the perforations and the film edge a fixed number of frames from the scene change. The tabs are detected by a metal detecting probe as they reflect a radio frequency emission. The signal produced is used to activate the light change mechanism.

The advantage of this system, which was devised about 1969 and is still in use in laboratories today, is that no notches are cut, but the early versions, in particular had several disadvantages. The most serious is that sometimes the cue tabs fall off or even move! Secondly, the adhesives were originally similar to clear adhesive tapes and solvent cleaning cleaned them off! After many years these tabs either pop off as the adhesive dries or the adhesive becomes sticky and oozes out to stick onto other parts of the film. Cue tabs are unpredictable and many early films from about 1970 can still be printed using the original cue tabs as cues.

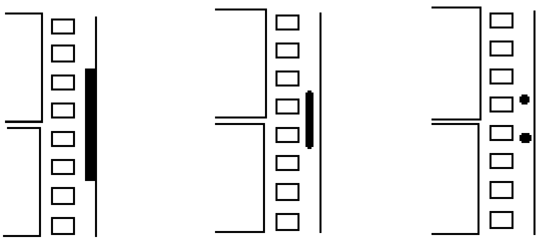


Figure 13.18 Different types and positions of metal foil cue tabs

13.8.5 FCC (frame count cueing)

Most modern printers are equipped for FCC and kits are available to fit this system to other printers.

A **'sync mark'** (a crayon or pen mark) is placed at the start of the reel on the leader and the number of frames counted to the first light change. The frame count information is recorded manually or on a punched tape or onto computer hard disc.

A synchronizer or specially adapted grading bench is sometimes used to determine the frame count information.

Some video colour analysers are equipped to use frame count and the data is then recorded at the grading stage eliminating the separate job of cueing. Whatever method is used to record the data it must be transferred to the printing machine. The most used systems are to use punched paper tape, network the computer directly to the printing machine, or use floppy disks to transfer the information to a computer at the printer.

There are two broad types of FCC techniques. The **milestone method** is when the light changes are recorded as frames counted from the sync mark which is designated as a frame count of zero. For example, the light changes could be at 115 frames, 396 frames and 1320 frames from the sync mark.

The second method is called the **batch method**. In this case the frame count recorded is the distance between the light changes. The printing machine is programmed to make a change a certain number of frames after the previous change. The frame count is reset to zero after each change.

In the example above the light change data would require changes at 115 frames, 281 frames and 924 frames. This is illustrated in Figure 13.19.

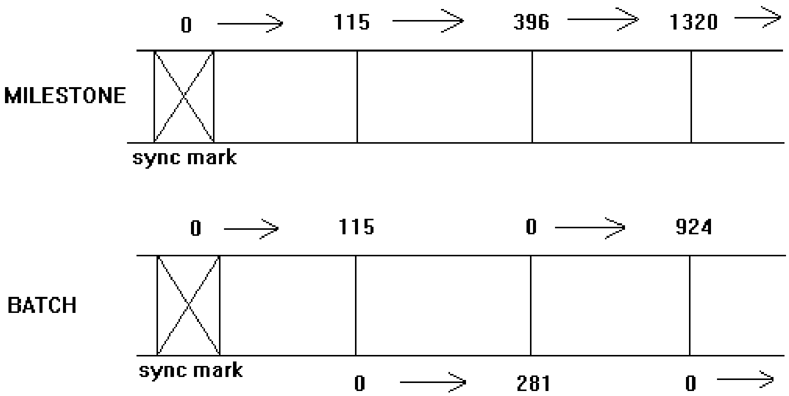


Figure 13.19 Milestone and batch frame count cue standards

Frame count punched tapes are of two types: either two separate punched tapes, one for the FCC data and another for the printing lights required at each cued change. Alternatively, a single tape with both the FCC and the printer light data as a **composite tape**.

FCC is ideal for interfacing with computers and speeds up the cueing time. It does not require the film to be damaged or handled by any additional procedure other than that essential for grading. The only real disadvantages of FCC are that special equipment is needed to check, or to read off the cueing positions or printer light settings. This is no great problem today as almost all laboratories use this system, but in the future it may be difficult to reconstruct the system once FCC has been replaced by something else.

13.9 PRINTER LIGHT CHANGES

Cueing the film by one of the methods mentioned above is to programme the printing machine to make a change in the printer light settings as defined by the grader. In a century the number of techniques used to alter the light intensity and the colour of the light to the gate is beyond the scope of this book. To some extent the different systems are well documented as many were patented and the following takes representative examples of the most commonly used.

The very earliest printers were probably controlled manually by shutters operated by the operator, who read what was needed from a card. At least one early printer used an edge notch that made a 'click' as it passed the gate. The operator would hear the noise and change the shutter to the next setting.

Some early printers had hand-operated changes, for example the early versions of Bell and Howell Models D and J printers. A list of light settings was made out by the grader on a card and the notch on the film edge activated an arm on the printer that moved a pointer to the next light on the card. The light change mechanism itself was a shutter between the film and the lamp which was controlled by a dial and handle operated by the operator. The actual position of the shutter was mechanically stored so that the printer operator could set the handle after a light change ready for the next light.

Numerous entirely automatic systems have been devised by printing machine manufacturers. Some printers have a separate 35 mm band of card with holes of different sizes punched in it to let different amounts of light through. These are sometimes called **Waterhouse stops**. The cueing system causes the band to move at each light change, varying the light as required. This was the first system to be used for colour grading as colour filters can be stuck over the holes as well. Although this system was used from about 1915, it is still in use today on some slow optical printers.

Another system uses differing resistances in series with the lamp to vary the brightness of the lamp at each light change. The cueing system changes the resistance with switches. Some system is necessary to record the sequence of resistances needed.

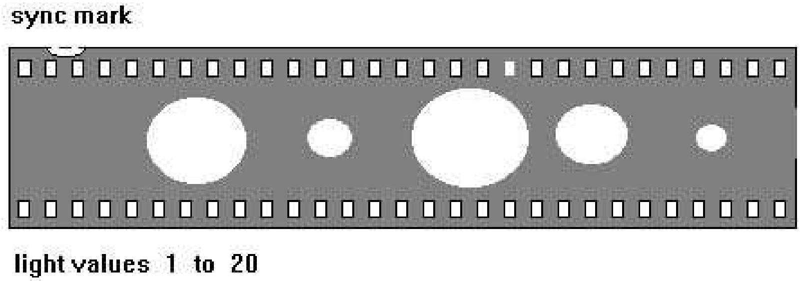


Figure 13.20 'Waterhouse stop' printer light control bands

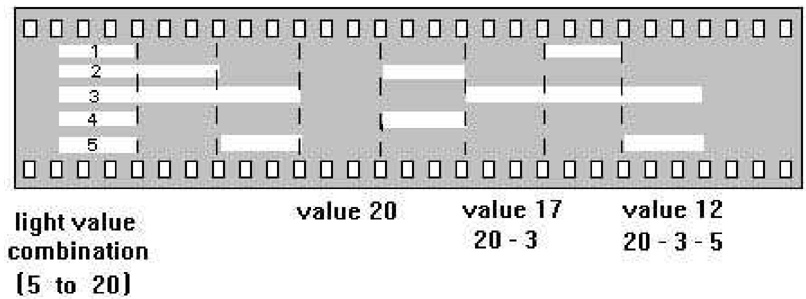


Figure 13.21 Union resistance printer light control bands

Modern printers employ **light valves**. These were first introduced by Bell and Howell in 1965 on their Model C printer and from that time all manufacturers have been using similar versions on all rotary printers and many others. The light intensity is varied by moving vanes or rollers or diaphragms and most comprise some form of motor that rotates eccentric rollers through precise arcs to rapidly change the total light passed between them.

The vanes or rollers are moved by mechanical linkage in mechanical light valves which are still very widely used, but those supplied today are the newer electronic light valves that use electro-mechanical means to move them.

Mechanical light valves have preset positions for the vanes corresponding to each printer light value, whereas **electronic light valves** are continuously variable allowing each light valve to be identically matched. Mechanical light valves require the next light value to be stored electrically because they are relatively slow in operation, whereas electronic light valves are almost instantaneous in action and do not need the printer light value information stored prior to the change.

The shortest distance between light changes will depend on the speed of the printing machine and whether it is a mechanical or electrical light valve. The mechanical light valve requires 6 frames between changes, the electronic 2 frames, at 180 feet per minute (or 48 frames per second) on 35 mm.

The amount that the light changes from one value to the next is known as a **printer point**. The value of a printer point was at one time different between one manufacturer and another but today is standardized at 0.025 log E so that grading data from one printer can be used on another. The printer points used today are sometimes called Bell and Howell (B&H) printer points. The amount of light is doubled every 12 printer points increase (0.3 log E) and the range of points is from 1 to 50.

Light valves are fitted with controls called trimmers or trims, to allow light valves to be adjusted and calibrated. There are 24 positions on the trims each of which also alters the setting by 0.025 log E. Neutral density filters can be placed in the light beam of a light valve to make gross adjustments of light and the trims are used to make fine changes to the light to adjust for the different speeds of stocks.

13.10 THE FADER MECHANISM

Most modern light valve printers have a **fader** fitted. A fader reduces the overall light reaching the film to zero at a pre-defined rate, or increases it from zero to set value. The point at which a fade occurs is determined by the printer light punched tape (see below). A special position on the tape has holes to pass the information to the printing machine to programme the start of a fade, its direction (fade up, or fade down) and the length of the fade.

The Bell and Howell Model C has six different possible lengths of fade: 16, 24, 32, 48, 64 and 96 frames.

13.11 A&B ROLL PRINTING

It is sometimes necessary to print a film by more than one pass through the printer; for example when we want to print one image superimposed over another or to make a dissolve, or on 16 mm, to hide the splices in the alternate black spacing.

In normal laboratory production A&B roll printing is only extensively used for 16 mm film and for archive purposes, the latter being the most frequently used.

Two separate grading programmes, tapes or bands, are needed for each printing pass, and the print stock must be marked to correspond with the sync mark so as to be able to repeat exactly the same position on the printer for each printing pass.

A&B roll printing is also used for printing special effects, such as dissolves and superimposition, especially of titles on picture. There have been some productions that use multiple rolls to create effects and the maximum number remembered by one of our authors was eight rolls, A to H! The Desmetcolor system of creating tinted and toned effects (see Chapter 14) is an A&B roll printing technique.

13.12 RACK CORRECTION PRINTING

Rack is the term used to indicate the position of the frame line relative to the perforations or relative to the next frame. 35 mm has a frame that covers four perforations, and on modern film (post 1930) the frame line is on the centre of a perforation. If the film has been cut and joined incorrectly so that one frame is cut off short with only three perforations, or cut too long, with five, the projected image jumps to a new position on the cinema screen. Before 1930 the frame line could and did alter and sometimes was not in the centre of a perforation but between perforations. Every 35 mm projector has a control that allows the gate position to be '**racked**' up or down to reframe the image on the screen.

Archive films vary in their 'racking' and some films may have sections in which the '**rack**' changes. The picture is said to jump '**out of rack**'. This could be due to faulty editing or to a genuine change of frame line position from one camera to another, or one printer to another. To correct on the projector each time is difficult and inappropriate (although probably commonplace before 1930).

The film needs to be put back '**into rack**'. This can be done by cutting out the offending part frame on the negative prior to printing, or by printing to produce a new print '**in rack**'. To do this the film with two different racks is printed, shutting out the light at each rack change. The film is then rewound past the rack error, the racking adjusted and printing re-started from the scenes missed in the first pass, closing off the light for the scenes already printed. This is only practical with some step contact printers.

13.13 COLOUR PRINTING

Colour printing in the past covered a wide range of techniques and stocks, but since about 1960 all commercially available negative and positive colour films have incorporated coupler colour integral tripack films, and tripack reversal films have been printed onto similar tripack reversal films. These materials are the basis of all present day printing for modern film production as well as for the colour restoration of archive colour film.

13.13.1 Subtractive printing

The subtractive system is so called because white light is used as the printing light source and subtractive colour filters in the beam modify the red, green and blue components of the light. Cyan filters reduce red light, magenta reduces green light and yellow reduces the blue light. The cyan, magenta and yellow filters are made in different strengths and described by their density to red, green and blue light. The weakest filters available have densities to their complementary colour light of 0.025 which corresponds to one printer point on the additive light valve system. The different densities of filter available are 0.025, 0.05. 0.10, 0.20, 0.30, 0.40 and 0.50 in the three subtractive primaries and also in the three additive primaries, red, green and blue. With this combination it is possible to make up any colour combination up to 0.50 in a maximum of three filters.

The Kodak filters for this purpose are designated CC (for colour correcting)/the density/the colour: so, for example, CC50Y and CC05R correspond to 0.50 density to blue (a yellow filter) and 0.05 density to cyan (a red filter), respectively.

Subtractive printers have filter positions in draws or slides positioned close to the condenser lenses or the filters are mounted on Waterhouse stops mounted at this position.

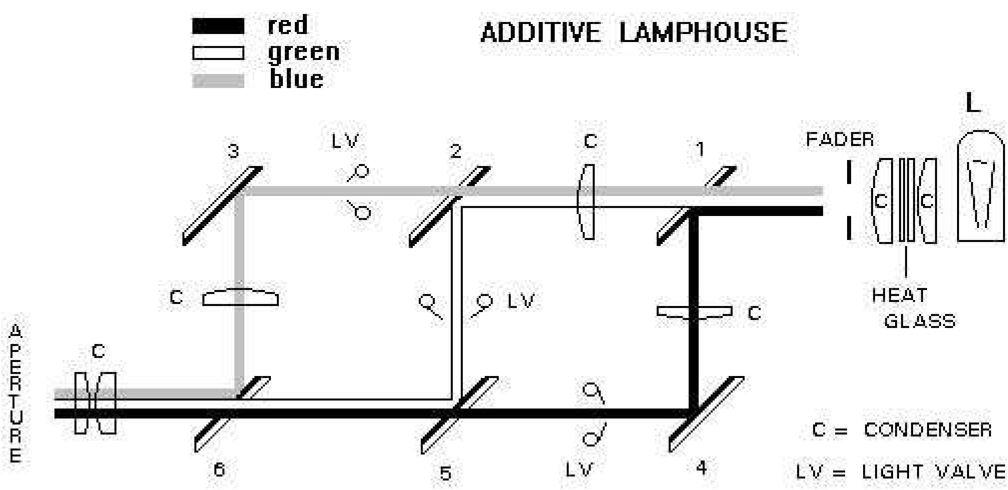
13.13.2 Additive printing

The additive system consists of exposing film to controlled amounts of red, green and blue light, each separately controlled in intensity, to create the exposure and colour required.

Almost all light valve light sources (see above) used on modern printers today are for additive colour printing, but can equally cope with black and white, by varying the R, G, B light settings uniformly.

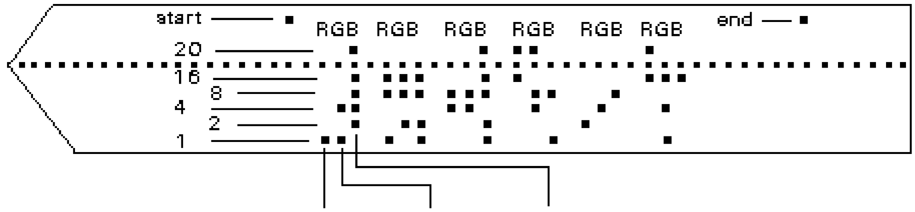
The lamphouse has a single light source and a beam splitting arrangement into three separate light beams. The three separate beams are passed through filters or reflected by dichroic mirrors to produce separate red, green and blue beams each controlled in intensity by a light valve. Dichroic mirrors are used in preference to filters as there is less light lost.

Thus the three separate light valves need three sets of printer point information at each cued change. Composite punched tape there-



DICHROIC MIRROR	REFLECTS	TRANSMITS
No 1	RED	GREEN & BLUE
No 2	GREEN	BLUE
No 3	BLUE	-- -- --
No 4	RED	-- -- --
No 5	GREEN	RED
No 6	BLUE	RED & GREEN

Figure 13.22 Bell and Howell additive colour printer lamphouse optical path



Scene	red	green	blue
001	01	05	50
002	25	26	27
003	12	15	47
004	36	32	09
005	02	04	08
006	36	21	16

Figure 13.23 Bell and Howell additive printer light control punch tape

fore carries cue data, and also the red, green and blue printer light values.

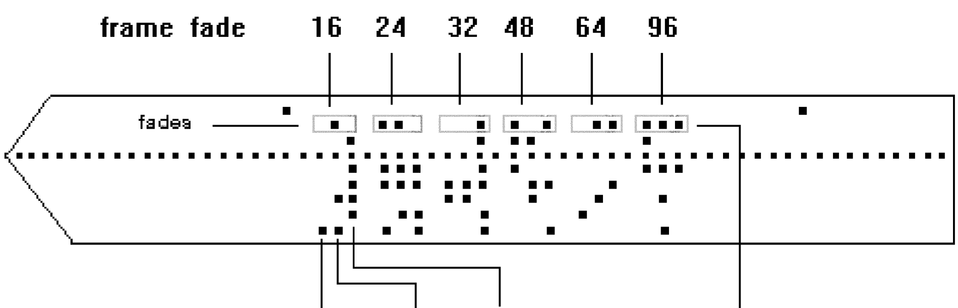
The punched tape used for printers is unfortunately not entirely standardized. The majority of laboratories use tape with the coding shown in Figure 13.23.

A number of companies use identical punched tape in the layout of the perforations but the sequence of red, green and blue data is not as shown above. This makes using punched tape from these laboratories (particularly from Technicolor laboratories) a little awkward and new tapes have to be produced.

13.14 PRINTER MASKS AND GATES

The relative position of the sound track and picture varies according to whether the film is head out or tail out.

When printing from an original negative it is usual to print the sound separately from the picture, often on the same printing pass through the printer but on a different gate and from a separate sound track negative. Although it is printed through a sound head normally, sometimes it is necessary to print only the sound area, or only the picture, through the picture gate of the printing machine.



Scene	red	green	blue	fade
001	01	05	50	16
002	25	26	27	24
003	12	15	47	32
004	36	32	09	48
005	02	04	08	64
006	36	21	16	96

Figure 13.24 Bell and Howell additive colour printer tape with fade control

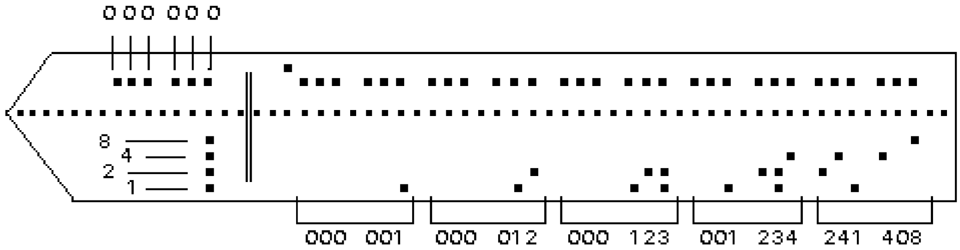
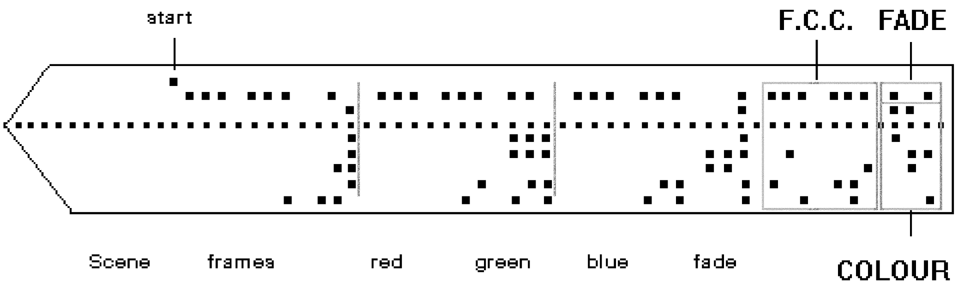


Figure 13.25 Bell and Howell additive printer tape with frame count: some printers used two tapes, one for colour exposure and one for frame count cue data



Scene	frames	red	green	blue	fade
001	000001	01	05	50	16
002	000012	25	26	27	24
003	000123	12	12	47	32
004	281234	36	32	09	48

Figure 13.26 Bell and Howell additive printer composite tape, carrying data for colour exposure, frame count cue and fades

Duplicate negatives are frequently ‘combined negatives’ in which the image and sound track are both present on the one film and only one pass through a printer gate is needed to print both.

For these reasons most printing machines have some form of adjustable gate or have masks that can be changed. The usual options are to enable the following to be possible:

- Silent frame, sometimes called a full mask, used for silent images and for combined duplicate negatives
- Academy mask with picture forwards
- Academy mask with picture backwards
- Academy mask, picture backwards, sound forwards
- Academy mask, picture forwards, sound backwards
- Sound heads also have forwards and backwards alternative positions.

Many of these alternatives were and are achieved by removable and/or relocating Academy masks which could be lifted out and turned round to alter the track positions.

There are a number of reasons why printing both forwards and backwards is useful (apart from the fact that the printing of multiple prints is possible without rewinding). One edge of the film might be damaged and printing in a particular direction can avoid problems. Also, if the film has Bell and Howell notches on one edge and Debrie notches on the other, for example (not uncommon outside the UK or USA), and it is decided to use the Debrie notches the film can be printed using the Debrie notches on a specific side.

13.15 SOUND PRINTING

Optical sound tracks, whether variable area or variable density, are always printed on a continuous contact rotary printing gate, even if the image is printed by step contact.

Even early rotary contact printers of the 1930s had a separate **sound head** to allow the sound to be printed after the image, so that the entire combined print could be printed in one pass.

Older optical and step contact printers rarely had an inline continuous head to print the sound until the 1960s, and a print made on one of these printers had the sound printed by a second pass through a special sound printer (or a normal rotary contact printer with a sound head).

13.16 SETTING UP A PRINTING MACHINE

There are many adjustments and variables that have to be correctly set on a printing machine before printing.

13.16.1 Control data

A printing operator will be provided with information from the Control Department of the laboratory for all the variables for the stock to be used. In small laboratories with no or limited automatic control the data need to be extensive.

Data can include:

- Filters or trimmer settings required
- Lamp voltage
- Diaphragm setting of lenses

13.16.2 From the grader

The grader provides all the other data for the specific job and will tell the operator in a small operation:

- Which printer to use
- Stock to use
- Gate and/or mask
- Machine speed
- Sound setting
- Type of cues used
- Shrinkage adjustments if any
- Frameline/racking corrections
- Image adjustment, such as degree of enlargement and alignment for optical printers

The printing operator may be simply provided with a work sheet with all this information or a computer reference that provides access to all the information and may also drive and control the printer cue and light system from networked PC data. Most archive laboratories are dependant on small scale equipment and require information to be passed on verbally or in writing. Modern film laboratories doing modern film work use computer aided printing to cut down on the errors, but even in large laboratories those departments specializing in archive film restoration are not unlike their archive counterpart.

13.17 IDENTIFYING RAW STOCKS

Surprisingly, essential experience needed in any laboratory is to be able to recognize a film stock in its unprocessed raw state and be able to recognize the differences between the emulsion side and back as a precaution against errors.

Colour stocks usually have a black coating on the base side of the film. This is called **remjet** (removable jet, i.e. carbon, backing) and is a dispersion of carbon particles in a binder. This is an anti-halation layer and prevents image light from the printing lamp, or camera lens, reflecting back from the base of the film into the picture area and reducing the edge definition and local contrast. It has the additional advantage that it conducts static electrical charges and therefore prevents static from building up in the film. It also reduces the possibility of damage to the film base before processing as it can be marked or slightly damaged by handling but is completely removed at the start of processing.

Black and white film stocks have three colours of base:

1. Positive films such as Kodak 5302 or Agfa-Gevaert T5.61 (discontinued) have a clear base which appears off-white before processing.
2. Negative duplicating stocks such as Kodak 5234 or Agfa-Gevaert T4.64 have a blue base which appears purple before processing.
3. Positive duplicating stocks such as Kodak 5366 or Agfa-Gevaert T3.62 have a clear base that appears yellow before processing.

The emulsion side of a film is almost always matt or semi-matt in appearance and the base side shiny; under safelight or white light this can be seen best by viewing a reflection of a nearby light source on the film surface. The emulsion side is also slightly tacky when dampened and most operators learn to distinguish between emulsion and base in total darkness by touching the film surface to the lower lip: the emulsion sticks; the base doesn't.

13.18 STORAGE OF PRINT FILM

Motion picture film stock is expensive to buy and by the time it has been through a printing machine and then processed, it represents a considerable investment in time and money.

Unexposed film deteriorates with time but the deterioration will accelerate with bad storage. Film is affected by heat, humidity, light exposure and by exposure to penetrating radiation such as X-rays. Storing unopened film from the manufacturer is less critical than storing opened film as the film is sealed at the factory at the correct humidity but once the film can has been opened storage must be at the correct temperature and humidity.

Film stored at low temperature must be allowed to reach room temperature before opening the can otherwise the humidity in the air will cause condensation on the cold emulsion surface causing damage.

Even if the film is stored under correct conditions it should not be kept for longer than the manufacturer's 'use by' date on the boxes.

Film is supplied by the manufacturer wrapped in black bags to prevent light fogging should the can be opened in unsafe conditions, but their effectiveness should not be relied on.

Once film has been exposed it must be processed as soon as possible as the image does diminish with time and temperature. Exposed film can be stored in a refrigerator or freezer before processing and there are some complex instructions from manufacturers for doing this repeatably. However, it is simply much better to process within the next few hours rather than be involved in a constant time and temperature keeping regime.

13.19 SAFELIGHTS

All film stocks are sensitive to light, this being fundamental to the photographic process. However, different stocks have different colour sensitivities depending on their purpose.

There are three broad sensitivities of black and white film in use:

1. Blue-sensitive films are, as the name implies, only sensitive to blue light. This enables a yellow safelight to be used. Blue-sensitive films are used to print from black and white originals.
2. Orthochromatic films are sensitive to blue and green light. Some sound recording films are orthochromatic in order to give increased emulsion speed. These require a red safelight.
3. Panchromatic films are sensitive to blue, green and red light, the full range of the visible spectrum. This is used for stocks used to duplicate from a colour original and colour stocks themselves. The most common safelight for these materials is dark green or brown (dark yellow) as the human eye is particularly sensitive to this central area of the visible spectrum. In general there are no true safelights for panchromatic and colour films as all light will fog the film given sufficient time.

As a rough 'rule of thumb', if film is exposed to a safelight 2 m away for 5 minutes and no additional density occurs over the base level, the system is safe. Safelight filters fade in time or are burnt by heat and eventually allow through other wavelengths, so they have to be checked periodically.

14

Grading

14.1 THE PRINCIPLES OF GRADING

The grader, called the 'timer' in the USA, is the technician responsible for defining the printing conditions of a negative (or any other element to be printed) and is thus responsible for the general picture quality achieved by the laboratory from that element. Grading is the process of estimating the printer cues and printer lights needed for each scene. There are a number of devices available, based on video displays of the element in a positive form and known as analysers or video analysers, that simulate the appearance of a print under printing conditions, by scanning the negative. Some black and white grading is still carried out by graders who view the original negative or element and assess the printing conditions by experience. This is known as **sight grading**.

Grading, especially sight grading, always results in a proportion of scenes that are incorrect at the first print, requiring correction at a second printing. Equally, sometimes the grader will assess a scene differently from the client – whether archivist or commercial customer – also needing a second try. This is true for all work, archive or not, and a set of terms and a production procedure has grown up over the past 100 years of film laboratory work that is also reflected in the methods commercial laboratories use to charge their customers for the work done. The first graded print made of any element is known as the **answer print**. This is shown to the client; it may contain minor grader's errors of judgement but generally is what the grader considers a good first print. Once the client has seen it and commented, a second print, called the **show print**, is made with the corrections. A good grader is one that needs few changes between these two. A client is charged for both these prints on a price per length basis.

Once a print is past the show print stage, it usually waits until the distribution procedure is planned. Television productions rarely go beyond this point, unless released for sale to cinemas or other TV companies. If a number of prints are to be made, the laboratory usually advises on whether one or more duplicate negative is needed, in which case this is made and a print made from the duplicate, called (in some labs) a **check print**, sometimes called a **control print**. This becomes the grading basis on which all the **release prints** are made. This broad procedure has existed since the 1930s and is applied to colour and black and white, whether negative–positive or reversal–reversal systems are involved. Technicolor imbibition printing used different terms and sequences. Archives that use commercial laboratories generally have a different arrangement due to the fact that, in general, a print, or old grading data, already exists that can indicate the original grading. Also archives want to reduce the cost of prints, so the two-print system is often replaced by a single print.

This works well in the majority of cases but inevitably there are instances when a second print with grading changes is needed. '**Re-grading**' or '**grading corrections**', to make this second print, or correct an answer print, are almost always carried out by the grader by sight, viewing the image in a theatre, on an editing table, or over a light box, at a 're-grade station', a location with a keyboard (or just a pad of paper!) that allows the grader to modify the original printing conditions and create a corrected printing programme.

All modern colour printer's printing lights and cues are driven by software, and increasingly the cueing and printing light data from the analyser is being stored on a hard disc and provided to the printer via a computer network. The additive lamphouses originally designed in the 1960s and upgraded by electronic light valves are the basis of all software controlled printers. In archive work many elderly printers are still in use either because they are able to handle shrunken film or because archive laboratories find it difficult to afford or justify modern equipment, and these are rarely controlled by computer software unless they have been fitted with a relatively modern light valve lamphouse compatible with software control. The Debrie Matipo printer, for example, can easily be fitted with a modern additive lamphouse. However, even quite sophisticated specialist laboratories that already have modern additive lamphouse printers for their modern production retain old printers for special purposes, and these often retain their original light control mechanisms. Grading using these old systems often has to be by sight, or by trial and error.

14.2 THE PERCEPTION OF IMAGES

14.2.1 Human vision

The grader needs to be aware of some of the characteristics of human vision, especially as they relate to viewing a projected image in a darkened room, a cinema.

The human eye is sensitive to brightness via the rods of the retina, which cannot separate colour, and this sensitivity is at its greatest for wavelengths around the green, peaking at about 550 nm. The cones of the human retina are assumed to exist as three different sensitivities, each able to separate approximate thirds of the visible spectrum, red, green and blue, and the sensitivities to wavelength overlap. Thus any colour is seen as a combination of red, green and blue signals, and brightness is primarily influenced by the rods, which cannot separate colours.

The process known as 'general adaptation' enables the iris of the eye to open or close to establish a consistent perceived image brightness even if the projector brightness varies. In practice, if the screen illumination is between 8 and 14 foot lamberts the brightness appears to be similar, and so these values have become standard aim screen illuminations, although today screens are often brighter than this.

The colours of any image will be dependent on the dyes present but also on the light source of the projector or viewer. Light sources are usually measured in degrees Kelvin or **colour temperature** – the higher the colour temperature the greater the blue component and the less red light component. Therefore the grader's judgement will be influenced by the projector light source, and theoretically a print will only be correct for a specific light source.

Several different light sources were used in the early days of the cinema, with open carbon arcs for 35 mm being the most frequent, and some use of incandescent (tungsten) lamps especially for 16 mm or smaller gauges. By 1965 the improved carbon arcs were being replaced by enclosed xenon arcs, and these are almost universal today.

The human eye is surprisingly adaptable and over a wide range of screen colour temperature, or colour, adaptation occurs, whereby the 'over stimulated' cones tire and after a few minutes of viewing in a darkened room with no permanent visual reference, the image perceived tends to become neutral regardless of the projection light source. The image colour balance needs to be within certain limits for an apparent 'neutral' or 'balanced' image to be seen but the effect occurs with both black and white and colour images. Pale tinted film quickly appears to lose the coloured effect.

The black and white images of the past have been quite variable in colour and were certainly not uniformly neutral even when not tinted or toned. The image colour of silver images depends on the developing agent used in the process, the presence of some other components in the process and the original manufacture of the film stock. The earliest developing agents produced images that included developing agent oxidation products, which were not neutral, and many early images were brown, sepia and even slightly greenish! However, after a few minutes' viewing they will all appear to be the same. The monochrome tinted prints also visually 'fade' in effect and some of the very pale tints would quickly lose their effect, although what was seen was the cut from one colour to another, before the next period of adaptation began. Strong colours are not adapted to and are seen all the time Interestingly, toned prints do not lose their visual effect so easily, probably because image was in tones from white to colour, and double effects, such as iron tone blue with a pink tint, can always be seen without any adaptation by the eye at all.

14.2.2 Colour perception

Adaptation to colour is an important aspect of colour grading, and the grader's job is to locate a colour balance that is acceptable and 'neutral' to the client or the viewer, and retain that balance from scene to scene. Changes in relative balance from scene to scene are often more disturbing than the overall aim. Television changed some of the 'rules' of grading as the TV screen is usually viewed in lit surroundings. TV grading standards are usually considered to be more stringent than those for the cinema. The European standard for viewing sets a TV colour temperature of 6500°K, Illuminant D, as being close to the standard TV tube but also close to daylight. In practice there is rarely any argument over whether an image is 'correct' or not, and grading is a precise operation although there is much that is not fully understood.

A colour grader must have good colour vision, and this can be tested using the simple tests for colour blindness by S. Ishihara (or the more complex 100-Hue test). About one in five men have some departure from good colour vision and about one in eight or ten women, and some countries use women graders exclusively because this is realized, and because it is felt that women make better, more confident, colour graders in particular. For some reason this is not so throughout almost the entire English speaking world, where graders (and telecine operators) are almost universally men.

14.3 SIGHT GRADING

Sight grading, estimating the printing conditions for a film image without an 'analyser', is possible only for black and white printing and for reversal colour printing. All grading was 'by sight' until about 1960.

14.3.1 Black and white/monochrome

A grader was trained by a process of trial and error, and by making a series of prints from a negative, seeing which was the best, and comparing it with the original negative and with the next negative. A grader rarely had any formal training and so it took months before a grader was allowed to work on his or her own. Some laboratories insisted on an apprenticeship system whereby the trainee worked with a grader for several years.

The control of the printer set-up was and still is fundamental to grading. The printer light should not vary so that the grader can learn a basis from which to plan their variations. Printer control probably did not exist until about 1930, and there are some well documented cases of arguments between printers and graders about the stability of the light sources which have parallels today. Today the most usual method of control is to expose a standard negative (today the Kodak LAD negatives are the most used; see below) and use the printer trims and lamp voltages to generate a single standardized print density, usually measuring this density to test its constancy.

Some laboratories used 'test printers'. Single negative frames from each scene, usually a frame from just beyond the scene used in the production, were joined in sequence to make a test strip. This was printed in the printer to be used for the final job (or a carefully calibrated special test strip printer) and the prints used as the basis for re-grading by eye. The process was fast and saved on print stock. These special test printers were certainly in use in USA from 1935, Technicolor had their own versions, and colour versions are still available today from Hollywood Film Co.

14.3.2 Colour grading

Sight grading is almost impossible with the modern masked negative, but was used before the introduction of the analyser, especially for unmasked negatives prior to 1955. In general early grading was by test strip or by trial and error.

14.3.3 Pre-grading

Most grading is negative–positive, but some reversal positive camera films were also printed onto reversal print film. In this instance a different procedure can be adopted from the sight grading, which was just educated guess-work, or the use of test strips. The procedure was known as 'pre-grading' in some laboratories, and is still in use today. Since both the original and the reproduced print are positives, the printing conditions are set up so that a print is produced that matches the original as closely as possible and these filtration and/or lamp conditions become a standard.

The grader views the original before it is printed (on a light box or by projection, and estimates the filtration or exposure needed to correct the original to what is wanted – if no change is needed, the printing conditions are left at the standard.

The procedure works as well with colour as with black and white. The exposure changes can be assessed by laying neutral, or coloured filters in the case of colour, on the original on a light box, and these same filters are more or less what will be needed to correct the print.

14.3.4 Re-grading

This is the procedure of making a correction to printing conditions based on a printed result in an answer print or a test strip. This is almost always by sight, even after an analyser was used for the first print. Many black and white graders rely on their experience and judgement to make these final, usually small, corrections, but many colour graders use filter aids.

A gelatine colour filter laid over the top of a print can help to see the effect of a printing correction. The filters used are usually Kodak CC filters that come in a range of colours, R, G, B, C, M, Y, and a range of densities from 0.025 to 0.50. These are the filters used for subtractive printing. The value used for the printing correction is half that of the filter needed visually (because of the increased contrast of the print stock). If the printer is using additive light valves the halved filter value is converted to additive printer points at the conversion of 1 printer light equals 0.025 log E.

14.4 VIDEO ANALYSERS

All grading was done by sight until about 1960, and early colour printing was therefore by trial and error. A test print was made, sometimes using just a few frames of each scene, and the result used as a guide to making the corrected print. The first colour negative–positive process was Agfacolor in 1936. The negative was unmasked but the grading must have been exceptionally difficult, and almost entirely based on trial and error. It is widely thought that this was the most difficult of all processes to grade because there was no analyser, but between 1920 and 1950 there were many colour systems that required grading during the printing stage, and the additive Dufay negative and the various two-colour duplitized films as well as the early Technicolor processes in which three layers of colour were cemented together must have been far worse.

The first video aid to grading was the Hazeltine Analyser, produced by a company specializing in aids for the graphic arts industry and as a 'spin-off' from a graphic arts colour analyser about 1960. This was a reverse phase scanner that displayed a video image of the negative as a positive and allowed the operator to alter the visual balance and brightness with controls linked mechanically to a display of the subtractive filtration needed to print that negative. The Hazeltine revolutionized colour printing in the USA and Europe to some extent but some of the major world feature film countries such as India and Egypt continued to use trial and error for another 15 years. In 1966 the Hazeltine was adapted to provide data for the additive lamphouse from Bell and Howell, and later Peterson, Hollywood Film Co. and Debrie. The Hazeltine has been upgraded since its original inception but it is still a unique device using fairly non-standard components and principles, and many Hazeltines in the world are now well past their best and the video images they produce are often only a little better than trial and error.

By 1965 it had been joined by the Kodak Video Analyser, a scanner with a TV display based on the field sequential display system of spinning red, green and blue filters in front of a monochrome tube supplied with RGB

Figure 14.1 A Filmlab Colormaster video analyser at Soho Images in London – a modern closed circuit colour telecine and display unit for grading colour negatives

signals in sequence with the filters. The picture was small (only about 200 mm wide) and the machine noisy, but these two analysers became the workhorses of the industry for 20 years. Today the original Kodak VCA is still used in some laboratories, joined by several others makes.

The dream of using a telecine unit such as a Rank Cintel adapted as an analyser has never materialized and this has proved to be a major weak link in the film system.

14.5 SETTING UP A VIDEO ANALYSER

The effectiveness of an analyser largely depends on the stability of the image. The grader uses a test negative, usually an LAD negative, but in the past the laboratories sometimes made their own by exposing film to a stage set with a grey scale and a local girl's flesh tone. The Society of Motion Picture and Television Engineers in the USA, Kodak and the British Kinematograph Sound and Television Society produced standard negatives which were often used for this purpose. These often had curious names that reflected their models or their origins, or the significance is simply lost – China Girl, Julie, Katrina and so on. Some had their origins in standard negatives produced by film manufacturers for still processes or graphic arts processes like Kodak's Dye Transfer Process.

The modern standard negative is Kodak's LAD negative – the Laboratory Aim Density negative – used for analyser set-up and for duplication set-up. The negative is placed in the analyser gate and the calibration adjustments made to produce a good image, with the printing conditions set on the analyser at 25–25–25 (RGB). The negative is then printed to produce a visual match with this image – an extremely difficult judgement to make – and the printer trims adjusted to achieve this result at preset values of the printer lights, also at 25–25–25 (RGB) (often called 25 across).

This simple explanation covers a morass of problems that has beset the laboratory industry for years, and which any client, whether archive or not, and including internal archive laboratories, needs to understand.

1. The picture display on all analysers never looks like the film image when printed, they normally look like a video picture. The result is that, however the grader makes mental adjustments, he or she can never see the print as it will actually appear, so that errors are inevitable. The correction is rarely precise. A well set-up digital telecine with various secondary corrections and masking facilities can generate a film-like image but this has happened only recently and at a price well outside that of a film laboratory. A film scanner display on, for example, a Cineon display, can also generate such a picture, but at 10 seconds per frame the operation would take too long as well as being even more costly.

2. The fixed gain/contrast characteristics of analysers rarely fit the products of the day and even reversal–reversal displays are rarely as accurate as pre-grading with hand-held colour filters!
3. The Hazeltine in particular has a very poor quality image.
4. Some analysers use non-standard components, so that they are awkward and often costly to maintain.
5. Only the Hazeltine and the Filmlab analyser can be fitted with 16 mm A&B gates (and no analyser has 35 mm A&B gates).
6. Ideally an analyser should:
   - have a motion drive facility, like a telecine or editor to show the moving image;
   - should have frame store to allow the retention of frames from elsewhere in a production.

   Few have these facilities.
7. The image must be absolutely stable and not drift – few are as stable as is needed.

14.6 USING STANDARD LAD NEGATIVES TO CONTROL PRINT QUALITY

14.6.1 The origins of LAD

The basis of the Kodak Laboratory Aim Density (LAD) concept is a simple inexpensive and easily used test film image to aid laboratories in making prints and exposing intermediates and internegatives in order to obtain good tone and colour reproduction in the final print. A standard film image with a patch with densities midway between the minimum and maximum densities is exposed on original camera film, and a duplicate negative is made that behaves in printing exactly like an original negative. This is the LAD image. The frame containing the LAD patch may be spliced into each film roll received by the laboratory for printing. The standard frame is then treated as a normal scene, and is always printed at the same printer balance settings. The rest of the roll (regardless of film type or origin) is graded relative to the standard frame using an electronic colour analyser, scene printer or trial print.

There are specification densities for the large grey patch in the LAD Control Film which if followed throughout each printing or duplication stage will produce good tone and colour reproduction, since achieving the aim density ensures that the range of densities falls on the optimum positions on the characteristic curves. These density values can be specified as aim values for a range of film stocks.

14.6.2 Description of the LAD image

The large white and black patches are used to evaluate the full tonal range. The white patch in the LAD Control Film scene is 90% reflectance and the black patch has 2.5% reflectance, which approximates to the range of reflectance found in most scenes. The unlit black plush area behind the girl's head provides a true shadow reference. There is sufficient flesh area for densitometry and evaluation of the flesh tone. The three colour patches (blue, green, red) are included to add a little colour to the scene and to help identify any colour separation exposures that might be made. The small grey scale at the bottom of the scene is used for subjective evaluation of grading and reproduction and can be used to objectively set the gamma controls on an electronic colour analyser.

14.6.3 Setting up an analyser with LAD

To aid in setting up a colour analyser, the frameline of the LAD Control Film is opaque so that it will produce a 'reference white' on the display. This 'reference white' will be a much whiter white than any white of highlight in the scene and is not affected by the setting of the analyser controls. The LAD patch and the six-step grey scale are along the bottom edge of the frame. A neutral density filter is placed at the lower left-hand corner of the analyser's display (i.e. on the face of the picture tube). The LAD Control Film is positioned in the analyser gate so that the 'reference white' frameline is displayed through the neutral density filter, providing a 'reference grey'. The calibration controls of the analyser are then adjusted to produce a visual match of the LAD patch with the 'reference grey'. A silver neutral density filter of 0.70 is a good starting point to produce an analyser display corresponding to a 1.0 neutral density. Also filters may be chosen to provide a reference for gamma adjustment.

14.6.4 Using LAD for printing control – procedure

Routine procedures for sensitometric and chemical control of processes must be well established. A daily check of printer light output is also important, usually with a printer photometer.

Run printer tests to establish the printer set-ups necessary to obtain the proper LAD densities on the intermediate and print films used in the laboratory as follows:

1. Prepare a printer test loop, including a processed control strip, and the LAD Control Film.
2. Print the printer test loop on to the intermediate, internegative and print films currently being used by the laboratory.
3. The LAD patch should always be printed at the 'normal' printer settings (such as 25–25–25) for the laboratory. Exposure adjustments for the different emulsion batches should be made using the trims or filter pack.
4. Read the LAD densities of the processed film. Make an exposure correction using adjustments to trims but retaining normal control settings, and reprint until the densities match the aim densities for the film stocks as listed in Chapter 34. The density change you should expect for each printer point change is also listed in Chapter 34.
5. Apply any densitometric cross-over readings that may exist between Kodak and the laboratory. Also correct for any known process drift.
6. The suggested practical tolerances for LAD densities for intermediate prints are as follows:

Answer prints	+0.08
Intermediates	+0.12
Release prints	+0.12*

*Differences between the three colours should not exceed 0.10 on prints. For example, Print No. 1 as described in section 14.6.7 below would be considered acceptable, while Print No. 2 should be rejected.

14.6.5 LAD control and the video analyser – procedure

1. Set the analyser control for the proper format, film tape, colour temperature etc.
2. Place the LAD Control Film in the analyser's gate so that the frameline will generate a 'reference white' on the display.
3. A 0.70 silver neutral density filter is placed in the lower left corner of the display tube over the 'white reference' to produce a 'reference grey'.
4. Set the control dials for the 'normal' printer set-up (25–25–25).
5. The calibration controls are adjusted to obtain a visual match of the LAD patch to the 'reference grey'. An experienced colour grader can easily obtain this match to within +1 print point.
6. Some adjustments in the density or colour of the reference filter over the display tube may be required. The 0.70 silver neutral density is merely a starting point. Increase or decrease the neutral density value or add Colour Compensating filters if needed until grading decisions made on the analyser agree with the prints. For example, if prints are consistently 10 CC red (when the LAD patch is on aim), the reference filter should be made slightly more red with a 10 CC red filter.
7. Other neutral density filters may be chosen to match the six-step grey scale along the bottom of the frame to provide verification of the contrast of the electronic colour analyser.

Note: Neutral Density Filters
Silver neutral density filters can be specially ordered from Kodak. They are called 'KODAK Flashed Density on Film', available in two sizes: 4 × 5 inch and 8 × 10 inch.

KODAK 'Wratten' Neutral Density Filter 96 can be substituted for the silver density filter. The WRATTEN 96 tend to be slightly yellow. Therefore, to make a grey filter, a 10 CC blue must be added to the WRATTEN 96.

14.6.6 Production grading – procedure

1. It helps to use a different colour punched tape to identify those customer jobs that are prepared using LAD.
2. Monitor printer and process using LAD to be certain the proper densities are attained. But, control printer and process independently.
3. Splice frames of LAD Control Film into each customer's original. It is best placed in the countdown leader around position 3 or 4. The first cue should be at the normal setting (i.e. 25–25–25) so the leader and LAD are printed at that setting.
4. Use the LAD printer set-ups on customer jobs as determined in the initial testing.
5. Duplicate negatives (with or without a LAD patch) are easily graded relative to the LAD Control Film using a colour analyser. A good duplicate negative should print at controls 29–29–29 (+5) relative to a LAD Control Film printed at controls 25–25–25.
6. Scene-to-scene grading from past jobs graded without LAD is still valid. However, a standard difference must be incorporated when printing.

14.6.7 Densitometric evaluation

1. Read the LAD densities of the processed film. Apply any densitometric cross-over readings that may exist between Kodak's reading and the laboratory's readings.
2. The suggested practical tolerances for LAD densities for intermediates and prints are as follows:

Answer prints	+0.08
Intermediates, internegatives	+0.12
Release prints	+0.12*

*Difference between the three colours should not exceed 0.10. For example, Print No. 1 below would be considered acceptable, while Print No. 2 should be rejected.

Print No. 1

		Print Dens.	Diff. from aim	Max. colour diff.
R	1.09	1.15	+0.06	
G	1.06	1.18	+0.12	0.09
B	1.03	1.06	+0.03	

Print No. 2

		Print Dens.	Diff. from aim	Max. colour diff.
R	1.09	1.12	+ 0.03	
G	1.06	1.06	0.00	0.16
B	1.03	0.92	+ 0.33	

Print No 2 would appear more blue than a 0.15 CC filter blue and would probably be rejected by the customer.

3. To make any density change, the approximate corresponding corrections in printer lights are given in Chapter 34.

14.6.8 Subjective evaluation

The close-up profile of the model will provide an immediate visual verification of correct colour balance when the LAD patch is printed to its aim of a grey of 1.00 visual density on the final print.

14.7 TRAINING A GRADER

The graders are some of the most expensive people in a laboratory – they are paid well but also influence both the quality and the output more than any other individual (except perhaps the Technical Manager). Rarely has any laboratory formally trained their graders, although the Colour Grader Training programme devised by Kodak at their Motion Picture Training School at Hemel Hempstead about 1968 has been available as a published document since then. This is reproduced entirely in Chapter 28.

The method was devised to teach a grader to use the additive lamphouse for colour grading. The student is shown a still single frame projected on a screen and makes a correction based on their judgement. The instructor then projects the corrected image. The images can be displayed by a projector or on a light box (with the help of a magnifier, as many graders work).

The laboratory can make as many 91 print sequences as they have suitable and varied negatives. Some of the sets should be of conventional scenes, long, medium and close-up, but a proportion of night scene, day-for-night scenes and other unconventional scenes should be included.

15

Principles of duplication and contrast control

15.1 INTRODUCTION TO DUPLICATION

No recent publication exists that summarizes the procedures for modern motion picture film duplication. Xeroxed papers are usually passed around within laboratory control departments and by manufacturers' technical representatives. Some optical effects technicians, even some laboratory technicians, may not be aware of the standard methods of using duplication films, and the techniques described here and in Part 4 may be the only published data for a generation.

From the introduction of 'Lavender' in 1930 to the introduction of Eastman Colour Reversal Intermediate Film in 1969, Eastman Kodak was the initial source of almost all duplication material concepts, and other manufacturers usually made duplication film stocks that parallelled the Eastman films. Today Kodak is almost entirely alone in providing both black and white and colour duplication stocks – and only Fuji provides a single alternative colour intermediate film.

Modern duplication film stocks are made for modern film originals and modern film print stocks, and are well suited for duplicating modern negatives (especially Kodak films). However, an increasing use is made of these same stocks for archive film preservation and to make restored prints from archive originals. Archive film restoration and preservation has always relied on the use of whatever duplication material is on the market, designed for modern film use, and used the films in a somewhat non-standard manner. Today this is true more than ever before.

As each duplicating film stock was introduced the manufacturer usually published a detailed paper describing its sensitometry and method of use, and a number of general papers were published in the 1960s in the *SMPTE* and *BKSTS* journals by Kodak technologists describing setting up procedures for optimum colour quality. These methods are known as 'full curve' setting up procedures (or sometimes as 'two point' procedures), and were initiated by Gale and Kisner. In the 1970s Kodak introduced the Laboratory Aim Density method (LAD) as a simpler procedure because the full curve methods were time consuming and were often not being done properly, or even used at all. Even now there are still optical houses and film laboratories that have never used any set-up procedure and simply guess at exposure and filtration.

Faded film, especially print films, are only recently being given increased attention. The chromagenic colour films of 1930 to 1970 are all now faded to some extent, and photochemical methods of restoration rely on adapting modern film stocks to allow masking and the production of a new duplicate colour negative. The methods are numerous and a few of the many published are listed in Chapter 18. Two-colour subtractive print films, which also fade or alter in colour with time, have received much less attention and the methods discussed in this book should be considered partly experimental.

15.1.1 Modern duplication practice

The reasons for duplicating operations in modern motion picture production are usually as follows:

1. A **finished** production may require a number of special effects such as fades, lap dissolves, wipes etc., and these are most

conveniently made by using duplicating steps. The duplicated section with the special effect is then cut into the final cut negative.
2. Duplicate negatives may be required as insurance against total loss of the valuable camera original because of abrasion or other damage caused by improper storage or handling.
3. Duplicate negatives are frequently needed for shipment abroad for foreign release printing.
4. Reduced or enlarged duplicate negatives are economical intermediates when format and size changes are made, for example where the original negative was 16 mm and a release print on 35 mm is needed.
5. In making reduction (e.g. 16 mm) prints from black and white or colour reversal originals, the preparation of internegatives offers economic advantages when larger quantities of prints are needed in comparison with making prints onto another reversal film.

15.1.2 Archive film duplication

In archive film restoration, duplication is carried for slightly different reasons:

1. To preserve the image.
2. To enable the image to be presented in the cinema without damage to the original.
3. To attempt to recreate the original image in a form approaching that of the original, eliminating the visual effects of damage, shrinkage, fading and decomposition.

This last process is commonly called 'restoration'. In some cases of restoration the objective may be to 'simulate' the original image without necessarily using materials or techniques that in any way resemble the original film or photographic principle. The Desmetcolor method of restoring tinted and toned films, for example, uses modern colour print stock and a unique exposure system.

15.1.3 Desirable attributes of duplicate and intermediate images

A duplicate negative, or any other duplicate element, is only a means to an end. The prime requirement is that it will have characteristics suitable for producing prints whose quality level is as close as possible to prints made from the original negative. This means that the tonal gradation, overall contrast, hue and saturation of the colours (in the case of a colour material), definition and graininess of the print made from the duplicate negative or intermediate must be as close as possible to that obtained in a direct print.

A common misconception is that a duplicate negative should appear visually and densitometrically like the original negative. Although this might be very desirable for a number of practical reasons, the materials used in the duplicating operations impose certain limitations, which make it impossible to achieve. Duplicate materials may have different base densities or different curve shapes or, in the case of colour, different dyes and masking. As a consequence, when original negatives are intercut with duplicate negatives, adjustments of the printer light intensity (and colour balance) must usually be made during final printing to give satisfactory prints from each. Obviously, the required changes must be within the range of light intensity and colour balance adjustments available in the printer to be used while still allowing for normal scene-to-scene corrections to be made. In almost every instance correctly exposed duplicate negatives, whether black and white or colour, will normally have higher image densities than the original negative and will require increased printer exposure (and possibly some colour grading changes in the case of colour duplicates).

15.1.4 Problems in duplication

1. Duplicating materials have a rather low inherent speed or sensitivity, generally in order to achieve as fine a grain and as high a sharpness as possible.
2. In some production situations, laboratories may feel that it is necessary to depart from optimum tone reproduction. For example, a thin duplicate negative may be prepared to be intercut with a thin camera negative in order to minimize colour grading and intensity changes, or a thin printing master may be prepared for use on a

printer having insufficient light intensity. This common procedure invariably leads to a loss in quality of the final print by introducing serious tone compression. This requirement quite frequently produces a better match with an original if the original is a rather tired colour release print that scrupulously following the rules. From this it can be seen that laboratories now, and in the past, frequently bent the rules to blend duplicate sections with the original or to minimize the grading effort needed.

3. A certain amount of variation between different batches of duplicating materials as well as variations in the process and printer may introduce some problems, especially when a colour duplicating film is used for making both colour master positives and colour duplicate negatives. This situation calls for careful testing of raw stock and strict control of process and printer variables to prevent losses in quality of duplicates.
4. Most film stock manufacturers used to make duplicating materials for black and white use, called 'fine grain' materials by Eastman Kodak, but recently most of these have been withdrawn from the market as black and white film is not widely used today.
5. Three general systems of colour duplication are still currently available, and the Eastman Kodak stocks are, again, those most used. Two of these are systems starting from a colour negative film and the third from a positive, such as a release print or a reversal original. All were devised by Eastman Kodak, although other film stock manufacturers also produce similar materials.
6. Specialist archive laboratories also use camera negative films for some duplication purposes because the colour and contrast characteristics of some just happen to be suitable for a special purpose.

15.2 EQUIPMENT FOR DUPLICATING

An intensity scale sensitometer having an intensity level and exposure time close to the conditions used in the printer (for example, the Kodak High Intensity Sensitometer type 6) is essential for the old but accurate two-point system of duplication. Silver or carbon step tablets having a density range of 3.00 and density increments between steps of 0.15 and 0.20 are the most commonly used. The LAD system does not require the use of any sensitometer but is limited to the simpler duplication routes.

The densitometer used for duplication work is critical, and the choice of filter or filters will depend on the film to be measured and, above all its eventual use. Chapter 12 contains this information.

In most other respects, for example the choice of printer and grading equipment, is the same as for any archive printing. However, once the initial printing from the archive film has been done the later stages of duplication do not need specialist printing equipment, capable of handling shrunken film, and conventional equipment is used.

15.3 TERMINOLOGY

English language terms used to describe the various duplication elements are confusing. Different laboratories and manufacturers used and use different terms, and in the case of Eastman Kodak, changed their terms at one point. In 1950 Kodak altered the term they used for Eastman Colour Internegative film to Eastman Colour Intermediate film. Several years later they introduced Eastman Colour Internegative film for a quite different purpose.

The following terms and definitions are not necessarily accepted standards but are those most commonly used. They demonstrate the confusion. The terms in **bold** are those used in this text.

CONSERVATION MASTER	**Term for a duplicate made primarily for long term archival storage**
DUPE NEG	A duplicate negative, usually referring to B/W only
DUPE POS	A duplicate positive, usually referring to B/W only
DUPES	1. A loose term for any duplicated film element 2. An interpositive, usually referring to B/W only, local term?
DUPLICATE	**1. A copy or reproduction of a film element, whether positive or negative** 2. A duplicate negative
DUPLICATION	**The procedure of making a duplicate (i.e. a copy) of a film element**
FINE GRAIN	1. A colloquial term for any B/W intermediate (negative or positive) made on any special duplicating film 2. B/W interpositive element made on Eastman Fine Grain Positive film **3. Kodak term for some of their black and white duplicating and printing films**
FLASHING	**The technique of giving print or duplicating film a low overall exposure to reduce contrast, e.g. by pre- or post-flashing, i.e. before or after the image exposure**
INTER-DUPE	A duplicate colour negative derived from an inter-positive; a local term, probably Technicolor
INTERMEDIATE	**1. General term for any film positives and negatives, colour or B/W made as intermediates between camera originals and final print** 2. A general term for interpositives on integrally masked Eastman Colour Intermediate film
INTERNEGATIVE	**An intermediate negative film, especially one prepared from a reversal camera original or a print, colour or B/W**
INTERPOSITIVE	**A term for any positive element used as an intermediate stage, i.e. not the final print**
LAVENDER	**1. Originally a Kodak B/W duplicating film with a pale blue base for making master positives (in the 1930s)** **2. A loose term for any B/W master positive**
MASTER	A general term for any intermediate stage
MASTER POSITIVE	**An interpositive made from a negative in order to prepare a duplicate negative, usually black and white**
PAN MASTER	A B/W intermediate, negative or positive, made on panchromatic film, usually Eastman Panchromatic Fine Grain film
PROTECTION MASTER	Sometimes the same as a conservation master, sometimes a term for positives made from camera separation negatives, especially Technicolor
SEPARATION MASTERS	**General term for any RGB separate records**
SEPARATION NEGATIVES	**Three B/W negatives made through RGB filters sometimes just two negatives (two-colour systems)**
SEPARATION POSITIVES	**1. Three B/W positives made through RGB filters, sometimes just two positives (two-colour systems)** 2. Positives made from separation negatives

15.4 THE CONTROL OF CONTRAST

15.4.1 The contrast rule

The overall image contrast of a copy, print or any duplicate stage is the product of the contrasts of all the preceding film materials. For example:

Black and white negative film	**Contrast 0.6**
×	
Black and white print film	**Contrast 2.5**
=	
Print contrast	**Contrast 1.5**

The optimum contrast for a subjectively acceptable projection print seems to be 1.5 for most audiences, and film manufacturers generally aim for this value. Some television systems aim for a lower contrast.

1.5 seems to be a good aim for colour as well as black and white, and the following are the Eastman negative–positive film contrasts:

Eastman Colour Negative film	**Contrast 0.6**
×	
Eastman Colour Print film	**Contrast 2.5**
=	
Print contrast	**Contrast 1.5**

All duplicating routes must be designed (or manipulated) so that the final print contrast is also the subjectively preferred 1.5. If the starting point is the same negative film stock and the print stock the same print stock then the intermediate stages must combined have a contrast of 1.0 to continue to achieve a final print contrast of 1.5.

Colour negative film	**Contrast 0.6**
×	
Interpositive film	**Contrast 1.0**
×	
Duplicate film	**Contrast 1.0**
×	
Print film	**Contrast 2.5**
=	
Print contrast	**Contrast 1.5**

In this instance the interpositive film and the duplicate negative film are the same film stock, Eastman Colour Intermediate, processed in exactly the same way to a contrast of 1.0.

The preparation of a black and white duplicate negative uses different film stocks for interpositve and duplicate negative developed to different contrasts, but still producing a combined contrast of 1.0.

Black and white negative film	**Contrast 0.6**
×	
Interpositive film	**Contrast 0.67**
×	
Duplicate film	**Contrast 1.5**
×	
Print film	**Contrast 2.5**
=	
Print contrast	**Contrast 1.5**

The Interpositive film could be a blue-sensitive material for use from black and white negatives or a panchromatic material for use from a colour film. This panchromatic film is also used for preparing separation negatives and positives (see Chapter 7).

The black and white duplicating film is always panchromatic and is also used to produce internegatives from colour or black and white prints or reversal originals.

Other duplicating routes, however complex or non-standard, will all follow these broad principles, and as a further example this can be seen in the use of Eastman Colour Internegative, originally designed for making a negative from an Ektachrome (reversal) camera film that could then be printed onto conventional Eastman Print film to make a print.

Eastman Ektachrome Commercial	**Contrast 1.0**
×	
EC Internegative	**Contrast 0.6**
×	
EC Print	**Contrast 2.5**
=	
Print contrast	**Contrast 1.5**

Ektachrome Commercial had a contrast of 1.0 and was originally designed to print onto a special Kodachrome print film. Today we use Eastman

Colour Internegative for making internegatives from a wide range of positives and, not surprisingly, may need to pre-flash to reduce the contrast of internegative to 0.4 to achieve a final optimum contrast of 1.5 if the original was a conventional print of contrast 1.5 also.

Projection print	**Contrast 1.5**
×	
EC Internegative (flashed)	**Contrast 0.4**
×	
EC Print	**Contrast 2.5**
=	
Print contrast	**Contrast 1.5**

15.4.2 The straight line principle

Characteristic curves of camera films and print films are frequently curved but in order to faithfully translate the exposures through a duplication system the intermediate film characteristic curves should be straight lines. All duplicating materials are designed to have long straight-line portions on which to expose.

To arrive at the correct exposure levels for any duplicating or intermediate film, one basic rule must be observed:

> **The full tonal range of the camera original photographic image must be printed onto the straight-line portion of the characteristic curves of all intermediate films.**

The characteristics curve of one record of almost any camera negative original, whether black and white or colour, shows a short curved portion in the lower densities (the toe), a long straight line portion and a curved portion at high densities (the shoulder). When the manufacturer's exposure recommendations for a camera negative are followed, most of the important picture information falls on the straight line portion of the curve (see Figure 15.1). The brightness levels of the original scene are reproduced in the negative in an undistorted relationship except at the highest and lowest brightness. The ideal, i.e. the most visually acceptable, exposure is achieved by positioning the lowest exposures, the shadows of a scene, low on the toe of the curve, resulting in some compression of the shadow detail.

To produce an intermediate or duplicate negative of high quality, a straight line or linear relationship between the densities in the original negative and the densities in the intermediate negative must be maintained to ensure a minimum of distortion, or the same relative distortion in reproducing the curve shape of the original negative. All intermediate or duplication film stocks are designed to have a long straight-line portion in their characteristic curve to accommodate the density range of the picture material as recorded in the original negative. By proper use of this straight-line portion a minimum of additional distortion may be introduced. However, the straight line portion of any duplicating material's characteristic curve does not begin at an effective density of zero; there is always a curve in the low density region, the toe. Therefore, the exposure given to any

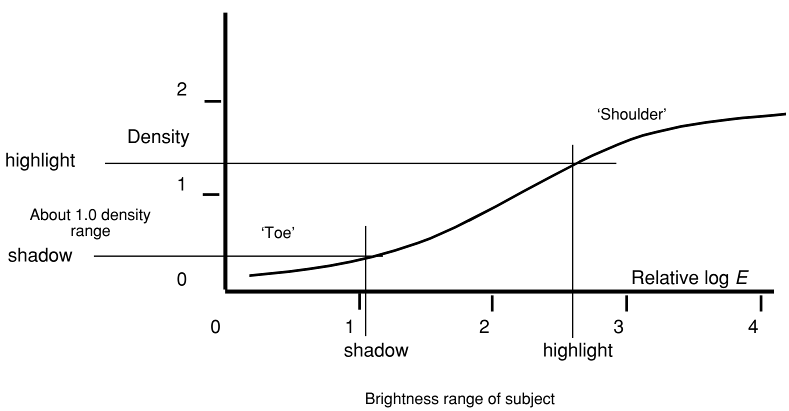


Figure 15.1 Typical characteristic curve of a black and white negative film, showing the range of exposures from a typical subject. Notice that the range of exposure does not all fall on the straight line part of the curve

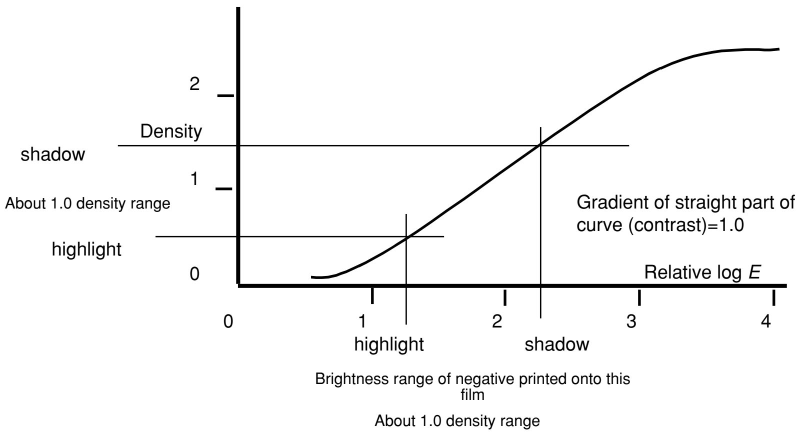


Figure 15.2 Typical characteristic curve of a duplicating film. Notice that the range of exposures selected for use falls on the straight line part of the curve

intermediate or duplicating film in both positive and negative stages must be sufficient to place the picture density range of the original camera negative on the straight line portion of the characteristic curve.

Original camera negatives often have important information in the lowest possible densities in a compressed form on the lower curved 'toe' portion of the characteristic curve. Any intermediate or duplicate negative is therefore almost always denser than the original as it is always 'placed' or exposed further up the curve in order to reproduce these relationships unaltered from the camera negative.

A thin, duplicate negative will be produced by using the curved lower portion of the duplicating film characteristic curve. The degree of distortion of the tone scale, which is introduced by this, will be more or less noticeable in various scenes, depending on how much of the scene brightness range is reproduced on the non-linear portion of the characteristic curve. A high key scene, for example, may show little or no distortion, since the restricted brightness range causes it to be reproduced entirely on the linear portion of the curve. On the other hand, a night, low key or dark scene will, for the most part, occupy the non-linear, lower part of the intermediate negative curve, and poor tone-reproduction characteristics will be evident in the final print, usually seen as 'smoky', low contrast shadows.

15.4.3 Contrast control

Contrast must be controlled to values that correspond to the requirements of the Contrast Rule. Contrast of a film stock is dependent on both its manufacture and its processing. During laboratory operations contrast of a film may be altered during processing or during printing or both.

15.4.4 Varying the development time

This is relatively straightforward in the case of black and white materials. The temperature of development, the constituents of the developer and the agitation all also play a part in contrast adjustment, but time is easier and more predictable.

In the laboratory the most widely used prediction of black and white contrast is the **time–gamma curve**. This is produced by exposing a number of control strips of the relevant duplicating film and processing at various development times (usually this is achieved in a motion picture film processor by varying the output speed). Fix and wash times also alter but do not have much effect if any on the sensitometry.

The curves of all the strips are plotted and the contrasts measured, usually gamma, the slope of the straight line portion of the curve. A graph plotted of the contrast against the gamma is the time gamma curve for that stock in that processor and any contrast within these limits can be achieved by interpolation.

In the case of colour materials, changing the manufacturer's aim contrast is generally only possible within narrow limits. Changes in development time alter the contrast of the three layers to differing extents and this can result in 'cross contrasts', where the differences

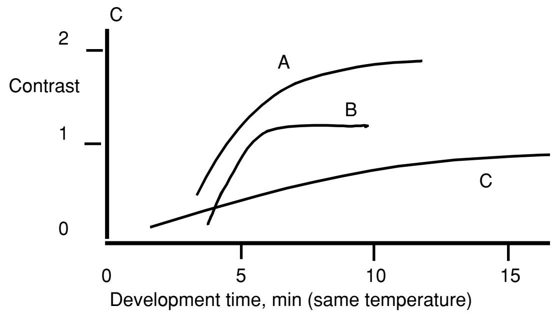


Figure 15.3 Development time–contrast or time–gamma curve of three black and white emulsions, A, B and C

show as varying lack of neutrality in highlights and shadows of the final positive.

A good example of this is where attempts to reduce the contrast of colour negative films usually results in prints with especially low green layer contrast – this is seen as magenta shadows and green highlights. This is not correctable by grading as reducing the magenta in the shadows increases the green (the complementary of magenta) in the highlights.

15.4.5 Pre-flashing

The technique of pre-flashing duplicating or print film, giving a small overall exposure to white (or coloured light) by a separate pass through a printer, is also widely used to reduce contrast. Again this is simpler on black and white film, and permits greater variations than available from development control alone, but more difficult on colour. However pre-flashing colour stocks can be very successful especially if filtered exposures are used to effect one layer more than another, and thus correct for some induced 'cross contrast' effects.

Pre-flashing will not usually be needed for routine black and white duplication because the process time can be altered to change the contrast, but will probably be needed for the following:

- Making a colour internegative from a stencilled print.
- Making an internegative from a duplitized two-colour print.
- Making an internegative from high contrast positives such as Kodachromes, Kodachrome prints, early Ektachromes and Agfacolor prints, and Technicolor prints.
- Making a combined duplicate colour negative from some Technicolor protection masters and almost all Technicolor optical fades and dissolves.

Extreme alteration of contrast on black and white film by altering development time alone is not enough.

The most commonly pre-flashed film is Eastman Colour Internegative, but also some colour camera negative films give excellent results when pre-flashed. Fuji Negative film and Eastman Colour Negative films have been successfully used and seem to be good at handling pastel colours of early stencilled and hand coloured prints.

15.4.6 Combined mask printing

A photographic mask is a secondary image made from the original image and combined, in register with another element (negative or

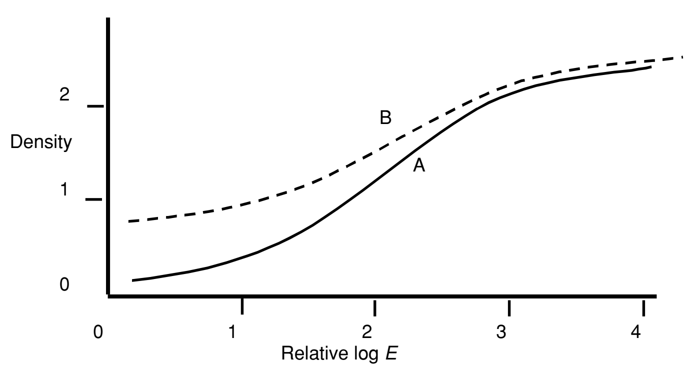


Figure 15.4 Effect of pre-flashing a film. A is the unflashed film curve, B is the same processing but after a pre-flash exposure

positive) in order to alter the elements' densities on printing. Masks were widely used to make major changes in contrast, and to cancel out the unwanted absorptions of poor subtractive dyes, in early paper print processes like the Dye Transfer process. In motion picture laboratories masks are hardly ever used for these purposes, as few printers can handle a 'sandwich' of film without difficulty and registration is difficult to maintain. Masks are used for special effect production such as the Travelling Matte system. Masks used for this purpose are called mattes.

A negative mask combined with a negative will increase the density range and therefore the contrast of the combined image. Conversely, a positive mask combined with a negative will reduce the density range and therefore the contrast. There are several references in the Bibliography, but in archive work the need for mask making is limited to the correction contrast caused by faded dyes in old colour films, but is very rarely undertaken.

15.5 USING A PRINTER AS A SENSITOMETER

A widely used and invaluable technique that is essential in duplication is the production of a 'print-through'. In order to establish that an image is printed onto the required straight-line portion of a duplicating material it is necessary to print a series of exposures from the original material onto the duplicating film. This can be done in several simple ways.

1. **Print a standard negative that includes a small step wedge** onto the duplication stock. The standard negative can be one produced by the Society of Motion Picture and Television Engineers in USA, or the British Kinematographic Sound and Television Society in the UK, or one produced locally by a laboratory. In every case the grey scale should be large enough to measure with a 3 mm densitometer aperture. The steps can be marked as corresponding to the highest and lowest discernible densities that exist within original work images, and used for the density plots in the set-up procedures described below. This procedure is less accurate than using a control strip, as there are fewer steps and it is less easy to interpolate. The standard negative is particularly appropriate to the LAD system.
2. **A control strip exposed by a sensitometer and processed for process control purposes can be used as a test strip**. The steps that correspond to the highest and lowest image densities can be marked on a control strip and the 'print-through' image of this strip will show the resulting densities. This technique is the one most often used in the 2-point set-up procedures that follow. The procedure is most easily used on a rotary contact printer, but an optical printer can still produce sufficient of each step to be read in a densitometer even though some of each step may be obscured by a frame line.

15.6 SETTING UP A DUPLICATION ROUTINE

The straight-line principle applies to both black and white and colour duplication. Setting up a duplication system can only be done using sensitometry. This can be done in one of two ways.

15.6.1 Two-point method

A full set up procedure involves the printing of a test negative or control strip, sometimes called the **two-point method**, or the Gale and Kisner method (1960) (see Bibliography).

The two-point method requires that full characteristic curves of the duplicating stocks are plotted and the positions of shadow and highlight from the original image be followed from stock to stock to ensure that they fall on the useful part of the curve. It can be time consuming but always produces the optimum result, and is particularly necessary when the process or the materials are being handled in non-standard ways.

15.6.2 LAD

A shorter, simpler method uses a single density step as a guide, called the **Laboratory Aim Density (LAD) method** (see also

Chapter 14). This is less precise for some archive routes, as it depends on Kodak having provided an LAD for the duplication route.

The LAD method utilizes a single mid-tone density (the LAD) on a standard Kodak-supplied negative spliced into and printed along with the camera original material during the duplication stages. If the LAD patch prints through onto the duplicating stock at certain pre-set density levels in interpositives, duplicate negatives and prints, then the correct exposure of the duplicate materials has been achieved. The procedure relies on the fact that processing is standardized and on the principle that most subjects have a fairly repeatable brightness range.

For this reason the LAD values can only be used where the processing method is exactly as specified by Kodak for that particular stock. Where the procedure used closely resembles the procedures used in modern commercial laboratories there will be a recommended LAD value available from Eastman Kodak, but LADs do not exist for many archive techniques. This is especially true where a film is being developed or flashed to achieve a non-standard contrast value.

15.7 BLACK AND WHITE DUPLICATION ROUTES

15.7.1 Flashing black and white films

Black and white films pre-flash easily but are rarely used, as their contrast can be easily controlled by development. Some camera negative film stocks are occasionally pre-flashed to achieve very low contrasts for use in exceptional circumstances.

15.7.2 Printing and duplication routes for producing black and white reproductions from colour

Panchromatic films are used to make the first duplication stage of a black and white reproduction from a colour film. This is essential in the case of tinted and toned films as well as natural colour films.

Optical blow-up and reduction can be carried out between 16 mm and 35 mm, or in order to magnify or reduce any other gauge to 16 mm or 35 mm. No other gauges are available as print stocks today.

16

Processing

16.1 INTRODUCTION

Processing is the term given to the chemical procedure of development of the latent image to produce a visible image and its subsequent stabilization.

The first photographic materials were emulsions coated onto glass plates or paper and for still photographs were processed by being placed in the chemical solutions in a dish or small tank. The dish was rocked back and forward to agitate the liquid and produce an even chemical reaction. Later (about 1885) celluloid film sheets were also used as a base and the film was processed in the same way or hung on clips in a deep tank of solution.

When the first process (the development) had finished, the material, on its clip, was lifted out, drained of surface liquid, placed first in a water rinse and then the **fix** solution tank. By 1895 the approximate timing of the procedure was:

- development, 10 minutes
- rinse, 30 seconds
- fix, 15 minutes
- wash in water, about 15 minutes

Some variety occurred, an acid **stop bath** replaced the rinse, and sometimes a **hardener** solution was inserted before the last wash. These early emulsions were very soft and could occasionally detach from the base and float away in the water.

It is difficult to know how long the earliest films were at the outset of cinematography, as no films longer than a few metres remain in archives from this period. The first celluloid films were made in 200 ft length batches and in 1900 films were being processed in batches of about 60 metres (200 ft).

Early cine film continued to be processed in about 200 ft lengths until the late 1920s, although a few large companies patented and presumably used simple continuous processing machinery from about 1920. Most film was batch processed. The 200 ft was wound round onto one of several different designs of rack before the entire rack was lowered into the processing solution.

'Pin-frames' were flat wooden crosses with pins or nails to allow the film to be wound on in a spiral. The solutions were in flat dishes. Another method was to wind the film onto huge drums 1–2 m in diameter and 2–3 m long, in a helix. The drums were dipped into the solutions and rotated to keep the film wet and agitated. These drums were also used to dry film and sometimes films processed on racks were rewound onto the drum while wet for drying!

Another system consisted of two 50 mm diameter wooden bars about 2–3 m apart, the film wound helically about 15 times, and the ends of the film secured to the frame. These were called frames in England and 'racks' in the USA. The racks were weighted and lowered into deep tanks, often made of porcelain and up to 3 m deep. After the development was over the rack was lifted, held to drain and moved on to the next tank for the next stage. In some literature there seems to be a distinction made between racks, which were as described above, and frames, described as a rotating bundle of rods around which the film was wound.

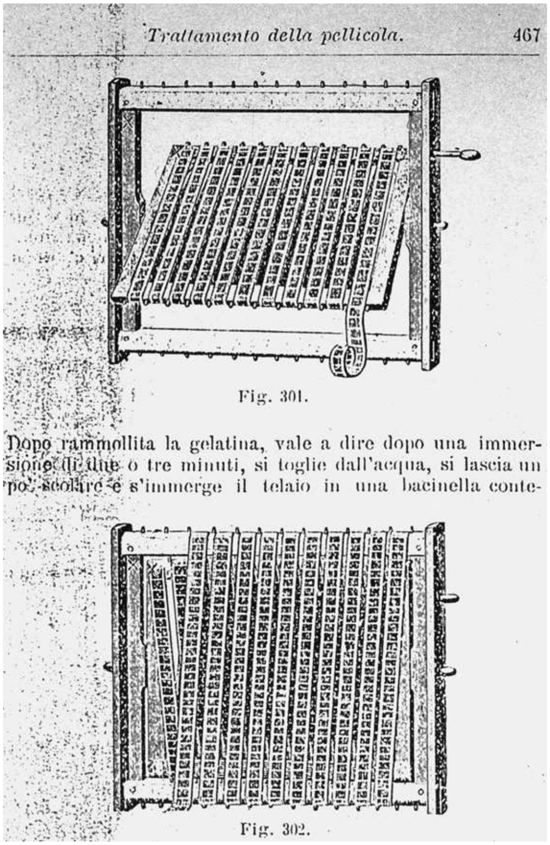

Trattamento della pellicola. 467

Fig. 301.

Dopo rammollita la gelatina, vale a dire dopo una immersione di due o tre minuti, si toglie dall'acqua, si lascia un po' scolare e s'immerge il telaio in una bacinella conte-

Fig. 302.

Figure 16.1 An early film processing rack: Italy, about 1910

About 1905 it seems someone (in the USA) thought of keeping a rack in each tank and pulling the film over the roller like bars in a helical manner and onto the next tank rack, as there were a number of patents issued. Some ideas seem unlikely to have been successful, but by 1910 at least some mechanized processing was being done in USA, England, France and Germany, but very little is known about the exact details in actual laboratories.

From 1920 onwards there were a very large number of patents issued but whether this meant that continuous processing was common it is difficult to be certain. The next main improvement came between 1938 and 1965, when it became possible to process the complex multistage colour processes at high speeds, that is faster than about 20 ft per minute.

From the 1920 three-stage black and white process at 20 ft/min (400 m/h – one-quarter of the speed of a camera), to today's colour processors at 11 000 m/h or 600 ft/min with up to 25 or more stages required, modern drive systems have been invented that can handle film gently at constant adjustable tensions as the film extends when wet and shrinks back as it dries.

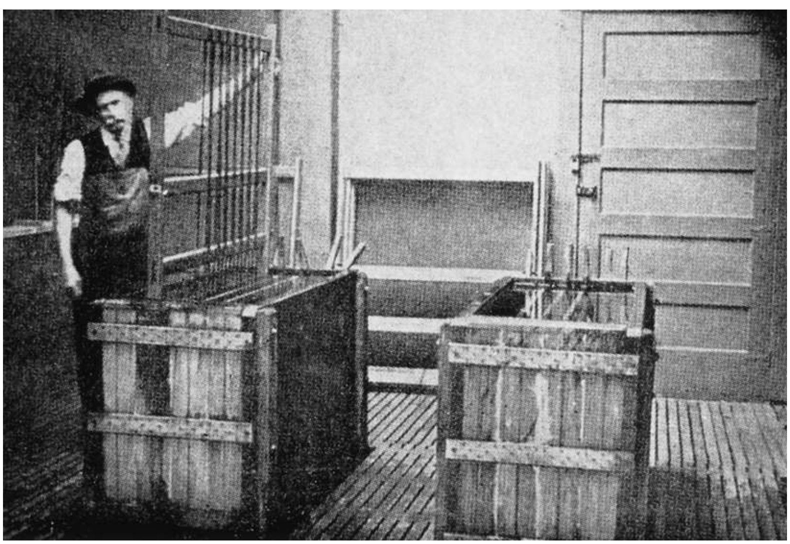


Figure 16.2 Processing a rack of film: Italy, about 1910

Figure 16.3 Processing print film on a rack: France, about 1920

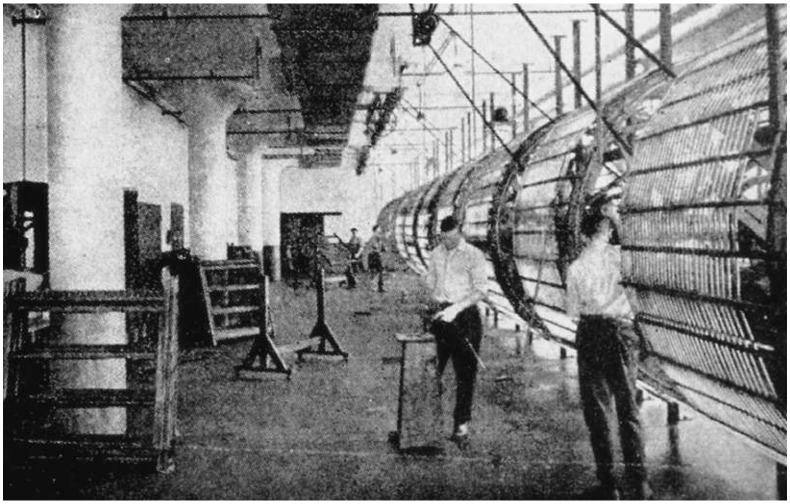


Figure 16.4 Drying film on open drums after processing on racks: France, about 1920

Figure 16.5 A modern black and white print film processor capable of 150 feet per minute (2700 m/h) at Henderson's Film Laboratories, London

16.2 THE BLACK AND WHITE NEGATIVE–POSITIVE PROCESS

A photographic image is formed when light falls on a photographic film resulting in a change in the materials on the film, which is invisible to the human eye. Photographic 'emulsions' consist of silver halide, usually silver bromide, crystals suspended in gelatine. When these crystals are exposed to light or other radiation, minute quantities of silver are formed. These minute quantities of silver are the image.

This initial image is called the latent (or hidden) image and in order to amplify it to a level when it can be seen the film must be 'processed', always, in the case of motion picture films, by soaking in a series of aqueous chemical solutions.

In all processes there are a number of essential chemical steps followed by washing and then drying. In addition there are usually additional chemical steps that are inserted in the sequence that are not essential but are there to ensure the process is controllable and repeatable, to improve the quality of the image, or to ensure that the solutions have a reasonable life.

16.2.1 Essential stages of the process

- Development
- Fix
- All processing is completed by washing

Development

A developing agent in solution converts the entire halide crystal on which there is an invisible latent image formed during exposure into black metallic silver.

> Silver bromide (exposed) + Developing agent = Metallic silver + Oxidized developing agent + Bromide ions in solution

The most common developing agents are **Metol, Hydroquinone** and **Phenidone.** None of these works very well independently, and they are usually combined as either Metol and Hydroquinone (an **MQ developer**) or Phenidone and Hydroquinone (a **PQ developer**).

The term **super-additivity** is used to mean that when these agents are paired in a solution together there is more activity than if the activity of each were added.

All developing agents oxidize easily; they absorb oxygen and become ineffective, usually going brown. To prevent oxidation a **preservative**, usually sodium sulphite, is also in the solution – this salt is converted to sodium sulphate by oxygen in the air before the developing agent and thus has a protective action. All developing agents operate only in alkaline solutions (i.e. of high pH) and sodium carbonate or borax (sodium potassium borate) is used in most black and white developers. These alkaline salts are called accelerators because the higher the concentration the more active the solution.

During development sodium bromide is released into the solution, which has the effect of reducing the activity, increasing the contrast and reducing the base density. Most developer formulations, but not all, have some potassium bromide added from the start. This helps to provide control and repeatability and ensures that replenishment does not result in major changes of activity (see below). In this context potassium bromide is sometimes called a **restrainer**.

Fix

The fix solution converts the unexposed silver bromides to soluble complexes. Sodium thiosulphate is commonly used, and the complex salts formed are often called argentothiosulphates. The white crystals of undeveloped bromide are dissolved and the film becomes transparent where they have been dissolved. The film is said to 'clear'.

> Silver bromide + Fix salt = Soluble silver thiosulphate complex

Some processes use **ammonium thiosulphate**, which is much quicker at fixing but more expensive, and many fixer solutions also contain a hardener to reduce the swelling of the emulsion and are usually acid as the solution is more stable when made acid.

Sodium thiosulphate is sometimes known as **Hypo**, because it was incorrectly known as sodium hyposulphate in the early days of photography.

Washing

The soluble complexes and fixer must be removed from the emulsion by efficient **washing** otherwise staining and fading of the image may occur; and as little as possible fixer should remain in the emulsion after washing.

The emulsion is then **dried** – the emulsion is very soft at this stage and should never come in contact with anything as it dries. During drying the emulsion, which swelled with water in the developer, almost returns to its original thickness.

A non-essential step is almost always inserted between the developer solution and the fix solution in order to stop development quickly. The developer solution is strongly alkaline and the developing reaction will only take place in an alkaline solution. To stop the development reaction the film is immersed in an acid stop bath.

Effect of developer chemistry on monochrome image colour

In many of the early development processes different developing agents were used to those of today and the resulting silver grains were different in structure and size. This together with the presence in the image silver of some insoluble decomposition products of the developing agents gave the images a different appearance to those of modern film processed in modern developer formulation. Early images were often slightly brown or at least slightly warm in tone and less neutral than those of today. This image colour is not easy to reproduce today, although several methods have been tried.

16.3 THE BLACK AND WHITE REVERSAL PROCESS

16.3.1 Basic principles

Special black and white film stocks can be processed in such a way as to produce a positive image directly in the course of one sequence of processing stages. Sometimes this type of process is called **diapositive** or **direct positive**. Technically, the reversal process is only one of several methods of processing a diapositive film.

- **First development** – this produces a negative image as before.
- **Bleach** – the silver negative image is made soluble and washed away leaving the unexposed silver salts.
- **Reversal exposure** – the unexposed silver salts are exposed to light and completely fogged.
- **Second development** – the remaining exposed salts are developed to silver and these are a positive image.

16.3.2 A typical reversal process

In practice, although these are the only essential stages, several other solutions are usually added to control the process.

A typical black and white reversal process is as follows:

- First developer
- Rinse
- Bleach
- Rinse
- Clearing bath
- Rinse
- Re exposure
- Second developer
- Rinse
- Fixer
- Wash

The first developer is essentially a normal negative type with the addition of a silver halide solvent, usually sodium or potassium thiocyanate.

The bleach is usually a solution of potassium dichromate and sulphuric acid.

The second developer is a very active solution containing sodium hydroxide to increase the alkalinity to make sure all the exposed halide is converted to silver, determined by the first developer.

After second development the film is put through a fixer to remove any small traces of silver halide left, washed and dried.

16.4 THE COLOUR NEGATIVE–POSITIVE PROCESS

Integral tripack colour films are the only photographic colour system used today for cinematography, and exactly parallel the black and white process except that the final image is comprised of three subtractive dyes, cyan, magenta and yellow, in three separate and discrete superimposed layers. Each layer has an effective sensitivity to red, green and blue wavelengths and the cyan, magenta and yellow dyes are produced in these respective layers by the development process.

The process of dye development principally relies on one group of developing agents, the **para-phenylenediamine** derivatives. Three insoluble, or non-diffusing, **couplers**, chemicals that produce dyes by reaction with oxidized paraphenylenediamine, are coated in the emulsion layers. The process of development produces the silver image and the oxidized developing agent also produced reacts with the adjacent coupler to produce an insoluble dye. The silver can then be removed.

The essential stages are:

- **Colour development** – this produces a silver image and the dye images.
- **Bleach** – the silver is converted back to the original silver bromide (leaving the dye images).
- **Fix** – the silver bromide is removed from both the image and the non-image areas.

16.5 THE REVERSAL COLOUR PROCESS

In this case a similar tripack is also used.

- **First developer** – a black and white developer produces a negative silver image.
- **Reversal exposure** – a light fogging of the undeveloped silver bromide.
- **Colour developer** – a colour developer that develops the positive silver image and positive dye images from the silver bromide not developed in the first developer.
- **Bleach** – converts all the silver (both negative and positive images) to silver bromide.
- **Fix** – removes all silver bromide into solution leaving only the positive image.

Some of these processes have many more solutions than these four. Stop bathes, clearing bathes, activators (to speed up the next chemical reaction), stabilizers (to protect the dyes from premature fading) and hardeners (to harden the emulsion for high temperature processing) have all been used, and many still are. As many as twelve different stages may be needed to process some colour reversal materials.

Almost all the colour films used today fall into these categories except for the Kodachrome (and some years ago, Dynacolor) materials.

Kodachrome is a ‘substantive’ process and a reversal material. The couplers that produce the dyes during colour development are soluble and are present in the developer solutions. There are three colour developers, each with one coupler and several reversal exposures are used to separately reverse a layer at a time followed by the relevant developer. The dyes produced are insoluble. This process can only work as a reversal process.

Washing and drying are as important and as critical with colour film as with black and white.

16.6 TYPES OF PROCESSING MACHINE

Processing machines can be categorized according to their method of loading, their drive system and their process, and the following features are important in their design.

16.6.1 Darkroom loading

The construction of this type of machine is such that the section of the machine that has to be in darkness or in safelight is in an area that can be light-proofed. The rolls of film are loaded directly onto the machine without using a magazine in the dark or under a safelight. When a safelight is in use it is possible to observe the film running through the dark areas and spot any problems that might occur. It is also possible to rectify some problems without fogging the film, as would occur with a daylight- or magazine-loading machine in the event of serious trouble.

16.6.2 Magazine loading

This type of machine is entirely in the light. The dark sections of the machine are covered with a lid and the film loaded onto the machine by means of a light-tight magazine. This has the advantage that maintenance can be done on the machine in white light without affecting any other machines that might be in the same area. It is not possible to rectify problems in the dark section without fogging the film.

16.6.3 Methods of drive

A major problem with all film, although least with polyester base, is that the wetting of the base, sometimes combined with a higher temperature than the ambient air, causes film to stretch by a small amount and to shrink back to its original dimensions as it dries. The effect is quite small but sufficient to create slack in the film path in the wet section and a dangerous tightening in the drier. Uncorrected, the film would not be driven as it comes away from the rollers, and in the drier will stretch or even break.

Over the years many inventions have been directed at providing a slip-free and even transport and several successful designs exist today.

16.6.4 Sprocket drive

The film is driven through the machine by means of sprocket rollers engaged with the sprocket holes of the film. The drive is often called ‘positive’ and the film runs at constant speed. The disadvantages are the risk of damage to the film sprocket holes and the expense and high maintenance cost of the sprockets.

The slack caused by wetting and the tautness caused by drying is compensated for by the bottom loop of each strand hanging free with a ‘diabolo’ type roller suspended in each loop. High speed modern processors use sprocket rollers at the bottom of each rack as well.

16.6.5 Tendency drive

The film is threaded over and under rollers fixed to the top and bottom of each rack in the same helical path. A constant speed drive roller positioned at one point near the beginning of the film path is run continuously at the required speed and feeds film into the process. Every rack has its top roller driven and as slack is created by the feed roller it is taken up by the top rollers. Tendency drive machines are still in use although they suffer from the problem that any break or stop in the film does not stop film being fed into the machine, so that something resembling a pile of wet spaghetti is the usual result!

16.6.6 Demand drive

Demand drive is the converse of tendency drive. The same helical rack is used but the constant speed drive roller, known here as the ‘pacer’, is at the drying end of the machine. The film runs over bobbins either pivoted with weights or with a spring mechanism. Tension on the film pulls the bobbin in contact with a plastic coated drive roller below, rotating it and transporting the film. In some versions the driven shafts are inside the sprung rollers rather than below. Some have the drive rollers at the bottom of the tanks, but most have them at the top.

Unlike the tendency drive, if the film breaks the film up to the break stops, but the pacer would then strip the film out of the processor beyond the break, so a **break detector** is fitted to stop the pacer immediately.

16.6.7 Soft touch tyres

The friction drive systems like tendency and demand are kind to the film, but at high speeds the film can aqua-plane and lose traction. The bobbins have soft plastic tyres of various patterns with raised block patterns or treads such that only small areas of film are in contact. The drive is positive but there is risk of damage to the film if a slip occurs, causing, usually, small backing scratches.

16.6.8 Modern processors

Today processors for camera films are almost always top drive shaft, demand drive, soft touch machines up to a maximum of 150 ft/min (2700 m/h) and print processors are exactly the same but up to 250 ft/min (4500 m/h). Faster print processors operate up to 700 ft/min (12 800 m/h) but generally use modern sprocket drives with a variable height bottom roller.

16.7 CONSTRUCTION MATERIALS

The manufacture of the various components of the processing machines must be from materials that are suitable for the purpose but also that will not affect the solutions. Stainless steel is used extensively for the high mechanical strength and where there is risk of corrosion. However, some stainless steels are attacked readily and it is usual to use steel of the US standard AISI 316. Some bleaches and stop baths can only be stored or used if titanium is used for metal parts. Some manufacturers choose to use plastics such as rigid PVC in this case.

16.8 AGITATION

If film passes through a developer without any form of agitation uneven development results. Additionally, chemical products of processing, principally sodium iodide and bromide, reduce the activity of the developer and local exhaustion of the developer occurs in areas of high density, if the solution is not continuously mixed. Several methods are in use to overcome this, sometimes in combination. All solutions are usually recirculated by being extracted from the tank, passed through some form of temperature control system and a filter and returned to the tank. The pump required for this purpose also provides local agitation. The need for agitation is greatest in the developer.

16.8.1 Spray jets

The recirculated developer solution is sprayed onto the film by spray jets below the surface of the solution. An entire technology has been developed to design the best spray jet nozzle. Some processes are more critical than others – the Colour Reversal Intermediate process (CRI) from Kodak, now no longer used, was notorious for requiring highly specific spray jet nozzles and very critical flow rates.

16.8.2 Sparges or drilled headers

These are tubes with holes drilled in them, positioned across the film strands below the solution surface causing several jets of solution to impinge on the film surface. They have the advantage that they are easier to clean and do not block as easily as sprays but they are not as effective.

16.9 SQUEEGEES

Squeegees remove solution from the film as it passes from one solution to the next to prevent contamination by 'carry over' of the solutions, and before drying, in order to prevent drying marks from uneven drying. Squeegees were originally just rubber wipers rather like windscreen rubbers but have developed into a technology of their own as machine speeds increased and the risks of contamination increased.

16.9.1 Squeegee lips or wipers

These wipe the solution from the film. They are made from rubber or plastic, often with metal or other types of inserts to influence the rigidity of the wiper. Some modern designs use very specialized plastics and are extraordinarily resistant to damage.

16.9.2 Vacuum squeegees

A small vacuum pressure applied between two sets of wipers removes the solution and lets it run to waste.

16.9.3 Air knives

Air pressure is used to blow solution from the film. They have the disadvantage that they are often noisy. Those using the 'Venturi' principle are the most efficient.

Contra-rotating, mechanically driven buffer rollers of felt, sponge or velvet are used in some processes as squeegees or as 'wringer-slingers' to remove backing or water.

16.10 WASHING

Washing has two purposes in a processing machine. First, to prevent carryover of chemicals from one bath to the next and second to remove the water soluble thiosulphates and argentothiosulphates produced by the fixing bath and any other chemicals that are present before drying the film. Sometimes the wash is followed by a solution treatment with stabilizers, fungicides or waxes.

16.10.1 Full tank washing

A constant feed fills the tanks full of water, which overflows to waste.

16.10.2 Counter-current washes

Clean water feeds the final wash and the overflow from that tank feeds to the previous wash and so on back through the machine. Only a single supply of clean water to the first tank is required.

This system gives great economy of water and is also the most efficient as the last wash is the cleanest.

16.10.3 Sprays

Spray washes consist of water sprayed onto the film as it runs through an empty tank. This system washes well but was too often wasteful of water in badly designed systems. Spray washes are rarely used today and were mostly limited to mobile processors in ships or planes as they take up less space than a full tank and if efficiently designed use less water than a full tank. Spray washing is almost always used for colour film sound track processors.

16.11 SCRATCHES AND THE CAUSES OF DAMAGE

All solutions collect particulate matter, and this is removed by filtration. Dust particles can cause scratches due to build up on the squeegee lips and on the rollers.

Other causes of scratches could be rollers not rotating or by film touching parts of the machine it should not touch.

It is good laboratory practice to run a scratch test before beginning to process film each day.

16.12 STATIC

Unprocessed film, handled in a rough manner, rewound too fast or used on equipment that is not earthed, can all cause the film to become electrostatically charged. These charges discharge either by the film touching a better conductor (like a human being) or the film touching an earthed item. The problem is caused by a spark produced that will give an image on the film. They usually look like lightning, although they can have other forms such as spots or lines, or at worst like images of trees! This problem is most common in the feed-on elevator of processing machines, and is usually eliminated by earthing the equipment or by filling the elevator cabinet with already positively charged air that counteracts the charges on the film.

16.13 DRYING

Both temperature and humidity of the drying cabinet is controlled so that the film dries at a reasonable rate and retains enough moisture to prevent excessive curl and brittleness of the film. The air flow is controlled so that there is a mix of fresh and recirculated air to dry adequately.

It is always recommended to adjust the temperature so that the film emulsion dries about two-thirds of the way through the drying cabinet. The point at which the film dries is the point at which the film changes from having a convex curl (with the emulsion on the inside) to having a concave curl. The remainder of the dryer time is used to even out the dryness.

Moisture removed from the film increases the humidity in the cabinet and the temperature also affects the final relative humidity. Control of the humidity in the cabinet is by varying the ratio of fresh outside air to the amount of air re-circulating within the cabinet. The humidity level in the cabinet will be more or less equal to the internal humidity of the final dry film. A relative humidity of about 50% is the usual objective, about the same as ambient air.

16.13.1 Shorelines

Film dried too quickly, usually due to too high a temperature, will exhibit shorelines. These are visible as definite contour lines often starting from the perforations.

16.13.2 Drying marks

These are a term for any mark left as a droplet of water dries. Inadequate squeegees are the most common reason, but hard water produces the worst marks and pure water, especially distilled water, produces virtually no marks even with poor ineffective squeegees.

16.13.3 Dirt

The main cause of dirt is a dirty drying cabinet, or dirty or ineffective air filters, and is seen on positive film on projection as fine black specks, and on negative film will print as white specks (and is called **sparkle**). The drying cabinet requires a high level of cleanliness. Any dirt in the cabinet will blow onto the wet film and stick to the drying emulsion and it may not be possible to remove this dirt without a great deal of difficulty, if at all.

16.14 REPLENISHMENT

During processing the active chemicals such as the developing agents in the developer are utilized and changed to inactive decomposition products. Also in development the emulsion releases sodium bromide that builds up in solution and in time slows the development action and increases contrast. In other solutions similar effects also occur.

Carry-over of solution from one tank to the next tank on the surface of the film occurs in all processes, the amount depending on the efficiency of the squeegees. To maintain a process with consistent activity it is therefore necessary to replenish the solutions in order to keep the chemical components constant.

A replenisher is a solution devised to replace some of the used process solution and, in doing so, bring the concentration of active chemicals back to the same level as the original fresh solution. A replenisher solution is usually formulated by the manufacturer of the film and the volume replaced is dependdent on the film processed. Replenishment may be **continuous** or **batch**.

16.14.1 Continuous replenishment

In these instances the replenisher is flowed into the tank at a constant rate dependent on the speed of the processor for as long as film is being processed. **Flow raters** or **flow meters** with a small glass or plastic ball that rises in a graduated glass tube are used to estimate the flow. The replenisher solution is either pumped or flows by gravity through the meter into the recirculation system of the process solution. In this instance there is a continuous overflow of solution in order to maintain the tank level constant.

An alternative and more modern system uses a time switch on a metering pump that switches on for a fixed period every so often, or a cam that switches a gravity feed on periodically. This method makes adjustments between different film gauges and different film stocks more easily automated.

16.14.2 Batch replenishment

This method was used for stills processing or for replenishing the early solutions that processed or tinted film on racks or frames. After each process a quantity of solution, depending on the amount of film processed, was removed and replaced with replenisher. A different formulation is needed from the continuous method above.

16.14.3 Calculation of replenishment rates

The most accurate method of determining the replenisher formula and replenishment rate (i.e. the volume needed for every 100 ft, say, of film) consists of analysing a solution for the individual chemical components, processing a relatively large quantity of film and then re-analysing the solution. From this it is possible to estimate the quantity of each chemical required in the replenisher to return the solution to standard, and the volume of replenisher solution required per foot or metre of film.

If analysis equipment is not available, standard replenisher formulae and rates are available from the film manufacturer and it is then possible to adjust according to the sensitometric results obtained. Almost all processes used in the world today were devised by Eastman Kodak. Other manufacturers make their film to fit these processes.

Some Kodak process and replenisher solutions are available in a pre-packaged kit form, both from Kodak and from other suppliers.

16.14.4 Leader rates

When running leader, the blank film that is used to 'lead' film through the processor, no chemical action is taking place. The chemistry is not being used, but there is always some carryover of solution from tank to tank on the film surfaces, so a low level of replenishment is operated just to maintain the solution levels. This flow rate for leader film is the **leader rate**.

16.15 BACKING

16.15.1 General

Backing is the name for the **anti-halation** coating on the base side of colour film.

A photograph of a bright light has a halo around the image of the light due to the reflection of the light from the film base. Backing is coated on the film base preventing high levels of light transmitted through the emulsion being reflected back to the emulsion, and causing a **halation** image.

The backing layer on most films is a water or alkali soluble layer of dye that is removed in the developer solution. The backing on many colour negative, positive and intermediate films consists of a light-absorbing material called **remjet** (i.e. removable jet) – a dispersion of carbon particles in an alkali-soluble layer. Black and white films do not have remjet backing and therefore do not need the additional processing stages of backing removal.

Additional advantages of backing are the protection of the base from scratches and the prevention of static because the backing is conductive.

16.15.2 Removal of remjet backing

The removal of remjet backing is by immersing the film in an alkali solution, called a **prebath**, that softens the binder of the water-soluble backing, and then in **backing removal** removing it by spray jets and rotating buffers. This solution also contains a high concentration of the salt sodium sulphate, which is photographically inert but which prevents the emulsion from swelling excessively. It is important that there are sprays on the emulsion side to prevent the backing from the base creeping round to the emulsion where it can stick and is difficult to remove.

Backing left on the emulsion is seen as smears of very fine particles under a microscope. The only technique that will remove them apart from rehashing, which is sometimes ineffective, is to use a very fine abrasive on the emulsion side and 'polish' it off. Brass polish like 'Bluebell' or 'Brasso', made of a fine alumina powder, was widely used.

Rotating buffing rollers, of lamb's wool, plush or a foam plastic, are used to ensure the complete removal of the backing.

16.16 COLOUR FILM SOUND TRACK APPLICATION

Black and white print films are exposed to the sound track in the printer on the same or a separate head to the picture, and the process is the same for both picture and sound. Photocells employed in projectors are sensitive to infrared radiation and silver has a high infrared density and a good signal to noise ratio.

Colour film sound tracks require a special processing stage involving a specialized **sound track developer applicator** in order to redevelop silver as the sound track. Many of the subtractive dyes do not have high infrared densities.

16.16.1 Colour positive films

These films require a single stage applicator. After developing the film, it is bleached normally to convert the silver image of both picture and sound track to silver bromide. Before fixing, the film is coated with a 'stripe' of viscous, highly active developer in sound track area, by means of a steel wheel running on the sound track area. The sound track developer converts the silver bromide back to silver. The result is a dye picture image and a combined metallic silver and dye sound track image. Usually the exposure of the sound track is limited to the top or top two layers of the emulsion to achieve the sharpest image.

16.16.2 Colour reversal print films

These require a double application stage. After the first developer, the sound track area is fixed by a viscous sound track fixer leaving only silver in the track. Later in the process, after bleaching the film image back to silver halide, the sound track is redeveloped by a sound track developer. Thus two application stages are required.

16.16.3 Defects of application

If the developer runs into the picture area instead of being restricted to the sound track area, black streaks or patches will be visible on the edge of the screen. If breaks appear in the developer application 'bead' then abrupt changes in sound level are heard. Breaks or variations in width of the bead are usually caused by a dirty applicator wheel, dirt in the solution, incorrect viscosity of solution, insufficient 'shaping' of the viscous bead, or incorrect levels of solution the wheel dips into. Frequent and close variations will produce a low frequency rumble.

16.17 IDENTIFICATION OF THE STOCKS

It is important that a process machine operator is able to identify different stocks by their appearance in white light. The colour of the emulsion and the colour of the base or backing, if present, are useful for identifying film. It is good practice to keep a sample of each film roll processed – just a few centimetres from the end of a roll, taken when the magazine is loaded – in order to check the type of film. A sample of each type of raw stock in use, mounted, one piece emulsion side up and one piece base side up, in a folder or on a card is a useful guide to be compared with an unidentified stock.

Another approach to identifying unknown stock is to '**dip test**' a short length. Take a piece of film and dip it into a black and white developer for a couple of minutes and then fix it, in the dark. After a brief wash it is usually possible to see the manufacturer's edge codes, the presence of a backing, and whether there is any colour masking or anti-halation coating.

16.18 PREPARATION FOR PROCESSING

The following checklist gives an indication of the degree of concentration needed by a developing machine operator.

1. The **temperature** of all solutions should be checked against specifications, particularly the developer(s).
2. Check that the **agitation** is operating in all developers. There should be visible movement on the surface of the liquid.
3. Check that all solutions are **circulating** through the heat exchangers and filters.
4. Check that the thermostat for the **drying temperature** is set to the correct value according to the specification.
5. Check that all **squeegees** are correctly adjusted and operating satisfactorily.
6. Ensure that all tanks are filled to the **correct level**.
7. Ensure that all **leader on the machine is in good condition** and all visible joins are in good condition. Make sure that all rolls of leader about to be used are in good condition and any joins are remade.
8. Check that the **alarms** for film break, end detection, solution over-heat and elevator **rise is/are operating**.
9. Check all **magazines** for **cleanliness**, and correct operation of all rollers and light traps and seals.
10. Ensure that all **replenisher tanks are full** and the **pumps** or other methods are **operating**.
11. All **re-exposure lamps** should be checked.
12. A **film bin** with cloth interior should be available at the dry end.
13. Check supply of **scissors, staples or tape, two staple guns or tape joiners** in case of malfunction, **cores, leader rolls, gloves**.
14. If the laboratory **standing orders** require it then **scratch tests** and **process control** wedges are run before any work is processed.
15. **Check labels of all cans of work** to verify that all the film is for the process that you are about to operate and that it all requires the standard process.
16. Turn on the **correct safelight** if this is permitted and turn off the white light.

17. Wind a few metres of leader onto a core.
18. **Open the first can**, lift out the roll, tear or cut a few centimetres of film and put it back in the can. If identification numbers are used then one should be stuck on the film and one on the can.
19. **Join the leader to the roll of film** and slowly **wind the film onto the core** running the film through your fingers to feel for tears or damaged perforations. If damage is felt and it is permitted, then the film should be broken and joined using staples or tape.
20. When the film is fully wound, **repeat (18) and (19) with the next roll** up to the maximum size for the magazine or feed-on plate.
21. If required, a **process control wedge** can be joined on and then a few metres more of leader.
22. **Load the film into a magazine** or **place in a can** if darkroom loading.
23. Ensure the **original cans** are **in the order** in which the film were joined up (so that when the film is taken off the dry end it can be put back in the correct can).
24. The small sections removed from each roll are checked in the light to make sure it is the correct film and also can be examined for scratches.

16.19 OPERATING A PROCESSING MACHINE

Whether running tests or work, the machine should be operated the same way.

1. The **replenishers** should be turned on at **leader rate**.
2. The **free end of the machine leader is attached to the magazine leader**.
3. All **joins must be checked** to see that they are neat and the perforations '**in rack**' if the machine has sprockets.
4. When the film reaches each bath the **replenishers are set to the specified rate**.
5. If sound application is necessary the **applicator must be started** before the film reaches it, and the operation of the **bead checked** as the film runs through.
6. While the machine is running, **constant vigilance** is required. A general watch is kept on the running of the machine looking for build-up of tension or any other malfunctions and temperature, replenishment rates, speed, washes and recirculation observed.
7. As the films wind up on the dry end the **joins are removed** and the **film put in** the **correct can**; the cans will be in the correct order.
8. When the run is complete **replenishers can be turned off**, and the **drying cabinet turned off**. If work is completed for the day all other functions can be turned off after the film transport has been slackened.

16.20 MAINTENANCE

1. The machine should be **kept clean always**, and any spillages of chemicals should be cleaned up at once.
2. **Squeegees** should be checked daily and adjusted if necessary and rubber or plastic squeegees replaced regularly.
3. **Filters** should be changed regularly on a planned schedule or if recirculation rates are falling.
4. **Buffers** should be changed regularly on a planned schedule.
5. **Sound applicator stations should be kept clean**, particularly the applicator wheels.
6. Any **leaks should be reported** at once to the maintenance staff.
7. **Drying cabinets should be cleaned daily**.
8. **Wash tanks should be emptied** at the completion of the day's work and cleaned to remove any build-up of algae regularly, or a biocide put into the standing water.
9. **Take care when dealing with chemicals** and chemical solutions. Gloves and protective glasses should always be worn whenever handling chemicals **also protective glasses**. If skin contacts any chemicals, wash them off immediately. Ensure that your hands are thoroughly washed after processing. Any adverse reaction to chemicals must be reported at once.

17

The restoration and duplication of early coloured films

17.1 INTRODUCTION

In 1918 William Kelley, subsequently the inventor of Kelleycolor, writing in the *Transactions of the Society of Motion Picture Engineers*, complained that he had several times been attracted to a cinema where colour films were advertised only to find that the film was coloured black and white. He was not the first to want to distinguish between 'real' colour films and tinted, toned or stencilled black and white films, which were far more common at that time. Kelley proposed that films be called 'natural colour' for the first and 'coloured' for what he described as 'films arbitrarily coloured by dyes ... to suit the individual taste'.

The problem still exists today and we can still use Kelley's terms to distinguish between **coloured** films and **natural colour** films. Natural or photographic colour film systems can be defined as those that have an analysis and a synthesis stage, and in which the reproduction attempts to stimulate the human eye in a manner similar to that of the original scene.

Many silent films were coloured, by tinting, toning, by hand painting and by the stencil colouring system. Tinting and hand painting was certainly in use before 1900. In the years after 1910 the makers of raw stock offered such a range of colouring recipes and the main studios and their laboratories had perfected such a wide variety of systems, that practically any colour could be achieved. The technique of colouring seems to have reached its zenith just before the advent of sound. By the end of the second decade the stencil colouring systems had almost disappeared and tinting and toning was used less, disappearing altogether by 1930.

It has been estimated that by the early 1920s perhaps 80% of all prints were coloured. Colour was not used necessarily as a representation of reality, but only a few references exist to the principles used in selecting colours (see the reference to Sonochrome films from Eastman Kodak). Sometimes only a few scenes in a film were coloured; more often the entire film was coloured using several different colours and techniques, with the colour changes linked to scene, location or mood changes defined by the director, or perhaps sometimes at the whim of the laboratory manager. Eric von Stroheim used a golden yellow overall tint for his symbolic gold sequences in *Greed*, and it is believed that some film plots were written based on the colouring to be used. Certain studios seemed to specialize in different colours perhaps to distinguish their products. In addition, due to the rather crude methods used for printing and developing, films (at least up until the end of the second decade) had marked differences in contrast and density from one scene to another, and the average cinema-goer was probably used to seeing many physical imperfections. Colouring, especially tinting, may also have served to cover up these defects.

Coloured films disappeared from the cinema as sound arrived around 1930 quite suddenly. There was no major technical reason why this should be so, even though the advent of sound and specialized (and expensive) duplicating materials made an appearance at this time. Once tinting and toning was no longer used it was certainly possible to make prints in one piece without positive joins, and it is possible that economy combined with improving sophistication on the part of audiences contributed to the change. Once colouring techniques were no longer used, the cinema became almost entirely monochrome black and white for many years throughout much of the world. Only in the USA and occasionally in Europe were a few films released in 'natural' colour before Technicolor prints became more frequent in the late 1930s. In effect, it seems that the world of the cinema became almost entirely black and white for more than 5 years, and in some parts of the world for more than 25 years, until the 1950s!

17.2 HAND COLOURED FILMS

Already in 1896 films were coloured by hand, frame by frame, using a very fine brush, and the technique probably originated from the hand colouring of lantern slides. The results obtained with this technique could be extraordinarily good, for example some of the works by George Melies.

The dyes used were translucent inks, paints or dyes in a water, or sometimes spirit base, and were applied by a brush or stippled on with a stippling brush onto the emulsion side. The gelatine of the emulsion absorbs water-based dyes easily. Opaque dyes were unsuccessful as they would appear neutral or black on projection. Probably the dyes used most were those used for stencilling and were the same aniline dyes used for lantern slides, but there is almost no literature on the subject.

The technique was limited to the capacity of the colouring artist and was never developed industrially. Furthermore, it was very difficult to apply the colour to a regular area of the frame without smearing and each frame has a slightly different amount of dye, covering a different area. In order to recognize this technique and separate a hand brushed film from a stencilled one, it is necessary to look at the variations from frame to frame, and in particular the difference in the spreading of the colour, the different amount of colour spread in an area, the lack of clean definition on the edges. This is often best seen as a fluttering of the coloured areas on the projected image.

It is quite common to be uncertain as to whether a film has been coloured by hand brushing or by stencilling if the hand brushing is well done, the stencilling haphazard or the dye rather pale or faded.

17.3 STENCIL COLOURED FILMS

By 1906 Charles Pathé, owner of Pathé Frères and a great innovator in the cinematographic industry, already employed 200 workers in his colouring studio in Paris. The method used was that of a manual stencilling developed by Melies and Gaumont: for each colour to be painted on the film a positive copy of the same film is stencil cut by hand and then the emulsion is washed away. For each colour, there is, therefore, a corresponding transparent outline, or stencil, similar to the stencils used for silk screen printing, with the part cut away where that colour should be.

In manual stencilling the worker holds the stencil in the left hand exactly superimposed on the film while, with the right hand, dips the paintbrush into the colour (usually a basic aniline dye, but dyes of all sorts were used), partially dries it on a pad and places it on the stencil. A light stroke is used to transfer the colour through the cut-out and onto the emulsion side of the film image.

The result was very precise (provided the stencil had been cut well), but the colouring process was extremely slow. Thus, when Pathé mechanized his production and expanded into markets throughout the world, he had to make some compromises in order to accelerate the process (the Pathé company coloured from 300 to 400 copies of each film by 1910). By 1908 a first version of the mechanical stencilling system was in use. The machine for cutting the stencils was extremely precise, based on a pantograph that enlarged the frame on a piece of opaque glass. The outline of the image that was to be cut out was traced on the glass by the operator using a pointer which guided the device (not unlike a sewing machine with an oscillating needle) that cut the stencil. The resulting stencils, one for each colour, was a length of film of the same length as the final print. The emulsion was then washed off. The machine for colouring the positive copies used a sprocket wheel which allowed a stencil and the positive copy to be pulled along together in contact. A velvet ribbon loop, continuously replenished with colouring agent from a tank, acted as the brush, transferring the dye through the stencil to the print. The procedure had to be repeated for each colour.

With the mechanized stencil colouring system as described in the patent literature of the time, it was possible to stencil a film with up to seven different colours at a time, in a single pass through the machine. Several investigators believe that even more than seven stencils were sometimes used. The process was used, with minor differences, by other companies as well, such as Gaumont in France and Ambrosio and Cines in Italy. The system was used less after 1915, though it lasted until the end of the 1920s (Pathé's colouring studio was closed in 1928), and it seems that the continuous stencilling machinery was considerably more complex than the film processing machinery at that time.

The Pathéchrome process, the trade name given to prints made using mechanized stencilling, used dyes applied on top of the black and white silver image, just like early hand colouring, and some of these dyes were the same as those used for dye tinting (see below). A list of nine colours was recorded in the Pathé literature and these are listed in Table 17.1.

These same nine colours seem to have been in use from early in the century to 1929. The actual dyes used may not have remained the same, however.

Table 17.1 Dyes used in Pathéchrome stencil production

Dye	*Grams/litre*	*Colour*
Diazol N1	5	Blue
Tartrazine	5	Yellow
Croceine Orange	7	Amber
Ponceau NR	20	Fire red
Acid Green Nd	4	Blue-green/cyan
Naphthol Green NB	5	Light green
Acid Amaranthe	2	Rose
Acid Violet	1	Violet
Ponceau NR	7	Orange-rose

Stencilling seems not to have been common in the USA. The Handscheigl Process of 1916 in the United States was used to colour some 15 or 20 movies and this produces prints with similar appearance.

The process used conventional lithographic printing to create separate printing plates to make up to three colours for printing onto a conventional black and white print. The areas to be coloured were defined by hand for every frame! De Mille's *Joan the Woman* was the first film to use this process, called then the De Mille Process. Eric von Stroheim's *Greed* also used it as well as printing onto yellow tinted film for some sections. The process was also called the Wyckoff Process.

17.4 FILMS COLOURED BY TINTING

The aim of tinting is to give the film a general colour without modifying the silvered image. When a film coloured with this system is projected the image appears dark on a coloured background.

There were three systems used for tinting films:

17.4.1 Colouring the emulsion using a solution of an aniline or similar dye dissolved in water

These dyes could be applied to the print after processing and the film was immersed in the aniline dye solution for several minutes to achieve the right result. However, there was also a market in unexposed film that had already been dyed so that laboratories could use this film to make prints. The dyes used for this purpose had to be fast and inert to the subsequent processing solutions.

In France, Pathé used the same nine colours that were used for stencilling, probably using the same dyes as well – not surprising, as the chemical requirements for stencilling and tinting are much the same.

A list of 16 dyes used for early films in the USA for tinting, stencilling or application by brush are listed by R. Ryan (1977) (see Bibliography). The various publications of the 1920s in both the USA and Europe list more than 100 in all. Ryan also lists a further 10 dyes that could be used for tinting sound film

Table 17.2 Typical acid dyes used for tinting silent film prints

Dye	*Grams/litre*	*Colour*	*US manufacturer*
Amaranth 40F	5	Red	National Aniline
Azo Rubine	2	Red	White Tar
Crocein Scarlet M00	2	Scarlet	National Aniline
Scarlet G.R.	2	Scarlet	Levinstein Corp
Lake Scarlet R	2	Orange-red	National Aniline
Wool Orange C.G.	1	Orange	National Aniline
Quinolin Yellow	2	Yellow	National Aniline
Wool Yellow extra conc	4	Yellow	National Aniline
Naphthol Green B conc	4	Light green	White Tar
Naphthol Green M	4	Light green	National Aniline
Acid Green L	4	Green	National Aniline
Fast Acid Green B	4	Green	National Aniline
Direct Blue 6B	2	Blue	National Aniline
Niagara Sky Blue	2	Blue	National Aniline
Fast Wool Violet B	2	Violet	National Aniline
National Violet 2RD	2	Violet	National Aniline

Source: after Ryan, 1977

prints without impairing the quality of the optical sound. These are listed in Table 17.2.

In practice, the emulsion was tinted by winding the film to be coloured onto a wooden frame or roller which was then immersed in a dye bath. The worker agitated the frame for about 3 minutes, then removed it from the bath when the desired colour was achieved and immersed it in a water wash for about another 2 minutes. The film was dried on the frame. Once they were dry the various scenes of the film were ready to be edited. Tinting reduces the visual contrast so that when the positives were made it was recommended that the contrast was increased to compensate. This does not always seem to be the case in practice.

One problem with this system was that the colours were never perfectly consistent because, depending on what level the section of film was on the wooden frame, and depending on the solution concentration and the time of treatment, the colour could be more or less intense. One instruction from the National Aniline and Chemicals Co. in the USA recommends a 50 US gallon tank (with concentrations as in Table 17.2 above) and suggests that between 20 000 and 40 000 feet of film could be dyed. Presumably the first racks of film came out more deeply dyed than the last!

It is recorded in the literature that even when tinting began to be done on continuous machines, the results were never perfectly uniform. Pathé was still using batch tinting in 1929, so perhaps continuous tinting hardly ever occurred. The main laboratories in the US seemed to have available about nine different colours at any one time. This technique can be used today.

17.4.2 Colouring the base (or the emulsion side) by applying a coloured varnish

This system was used in laboratories before pre-tinted positive printing film was introduced on the market. There is little information on how this was carried out. Examples seem to be discretely painted or sprayed on one side only. The description in the Agfa processing manual of about 1925 indicates that coloured lacquers were applied by roller to the image area between the perforations, of the film base, but film of this character has not been reported to the Editor [P.R.]. It seems that this technique was very uncommon.

Several film archive specialists have recently experimented with this procedure using some form of air brush to spray dye onto uniformly moving processed prints.

17.4.3 Using pre-tinted positive film on which to make the print

The inconsistency of the tinting, the technical difficulties that it posed for the labs, and the unpredictability of a toned image on an emulsion which had already been tinted (and vice versa), led the main film manufacturers to introduce raw stock coated onto film base that had already been tinted. This did not create any printing problems (the printing light does not pass through the raw stock base) and permitted a much more stable tinting that resisted better the heat of the projector lamp as well.

Most, if not all, film manufacturers offered some black and white print film on tinted base support as early as 1915. Nine colours were offered in 1910 by Eastman Kodak (called red, pink, orange, amber, light amber, yellow, green, blue and lavender).

As optical sound arrived in 1929, it was realized that sound prints could not use some of these dyes without a high amplification of the signal from the sound photocell and that this would result in a poor quality, especially at the high sound levels in cinemas. Eastman Kodak introduced a new range of coloured bases in 1929 as a series of print films called Eastman Sonochrome Tinted Positive Films specially for sound films. The names of the colours followed the pattern used by other manufacturers, suggesting the purpose of each colour and adopting the rather high flown language of symbolism common to the cinema at the time (see Table 17.3).

Eastman Kodak, Kodak Ltd, Agfa, Gevaert and Pathé offered such a wide selection of coloured bases in the 1920s that the market was saturated to the extent that at one time coloured print film stocks were sold at the same price as black and white! Its only disadvantage was that, since credits were generally shot directly and displayed as a negative (i.e. not printed from a negative), and the contrast needed to be as high as possible, they could not be shot on a coloured base film. The camera exposure of titles was generally through the film base (to get readable writing it was necessary to load the film back to front in the camera). For this reason some well-coloured films have credits that are in black and white at this period, whereas previously the titles were dyed in a dye bath along with the picture.

Tinted films are often dark, with between 25 and 95% of the projection light absorbed by the dyes. However, recently some of the prints that were previously thought to have faded to very pale tints are now considered to have been only delicately tinted to begin with. Tinted prints can be rather difficult to watch

Table 17.3 Sonochrome tints

Colour name	*Dom. wavelength*	*%Transmission*	*Colour*
Rose Doree	633	57	Deep warm pink
Peachblow	619	61	Flesh pink
Afterglow	603	66	Orange
Firelight	596	66	Yellow-orange
Candle Flame	585	75	Orange-yellow
Sunshine	579	83	Yellow
Verdante	520	57	Green
Aquagreen	505	40	Blue-green
Turquoise	490	46	Blue
Azure	484	28	Sky blue
Nocturne	476	28	Violet-blue
Purplehaze	455	38	Blue-violet
Fleur de lis	575	25	Blue-purple
Amaranth	557	31	Red-purple
Caprice	537	53	Cool pink
Inferno	508	36	Red-magenta
Argent	none	71	Neutral grey

as the eye becomes fatigued to being exposed to one colour for a long time, an effect known as **general colour fatigue**, caused by fatigue to individual colour receptors in the eye. In time, sometimes only a few minutes, the eye accommodates to compensate for the dominant colour and if the colour is relatively weak, after a while, the colour is not noticed. This was probably recognized by early film makers using tinted films as strong colours are often used for long scenes, whereas weak colours are sometimes frequently changed.

In the early 1930s tinted films disappeared over a very short period. Sound was not in itself the cause but the printing systems developed for optical sound prints meant that films were generally printed in one pass through the printer and no longer needed positive joins. Specialized duplicating stocks were introduced in the 1930s and these helped to overcome the problems of making large numbers of release prints from one original negative.

From 1930 to 1936 black and white reigned supreme and only in a few countries did colour make the occasional appearance prior to Technicolor imbibition prints. This disappearance of coloured films over quite a short period seems difficult to explain. There seem to be no technical reasons why coloured films could not continue to be made; neither the new sound technology nor the advent of specially made duplicating stocks meant that colour was no longer possible. If colour was still needed it could have been continued.

The new Sonochrome print stock, released on the US market in 1929 to make colour prints with optical sound, was withdrawn within two years.

Perhaps the viewing public no longer accepted these often unrealistic images.

In order to distinguish tinted from toned films, view the white parts that, with tinting (which colours the entire film), become coloured too. With simple toning the area outside the picture remains completely white, although this is not so well defined with mordant toned film in which the highlights and edges are often coloured or stained (see section 17.5 on toning). Tinting always colours the perforated edge of the film as well (except in the case of Agfa's lacquering method). Tinting of the emulsion can be identified by scratching the edge of the image on the emulsion side; if the colour comes away it is the emulsion that has been coloured not the base (or the base lacquered).

17.5 FILMS COLOURED BY TONING

Toning was perhaps less frequently used than tinting because it usually called for several baths for the (already developed) image to be coloured. However, some single solution toning processes did occur, especially Iron-tone Blue and the various red–brown tones.

Toning is the process of exchanging part or all of the original silver image for another coloured material. It had already been widely used for making coloured still paper prints but not all the paper techniques were suitable as the replacement material has to be at least partially translucent to project a coloured image. Totally opaque dyes would simply be seen as black on projection. However, the lantern slide industry had already tried out most techniques and undoubtedly the new motion picture industry learnt from this.

Toning colours the dark parts of the image leaving the clear parts unaltered since only the silver image, or part of it, is removed and replaced with another metal salt, a coloured dye or a coloured silver salt. It is therefore usually quite easy to distinguish a toned image from a tinted one provided the tone has not faded. **Sepia toning**, in which the silver image is replaced by reddish brown **silver sulphide**, was originally quite a fiery ginger colour by reflected light but this fades over the years to a dark brown that is sometimes mistaken for untoned silver.

The most common form of toning (even now sometimes used in still photography) consisted of transforming the silver (which is neutral and opaque) into inorganic coloured salts of other metals. This is sometimes called **metallic toning**. Using this procedure only a restricted number of colours could be achieved: red or red–orange (an image of copper or uranium ferrocyanide), and blue (an image of ferric ferrocyanide, also called Prussian Blue). Less commonly vanadium (greenish-brown) and chromium (brown) salts were also used. The Eastman Kodak manual on tinting and toning recommends vanadium for a greenish-brown, but this colour is rarely seen (or rarely recognized).

Generally, metallic toned films are rather unstable and tend to decay more quickly than the tinted films probably due to the fact that some metals accelerate (i.e. are catalysts for) the cellulose nitrate base decomposition process. Sometimes the decay of the toning means that the dark parts are affected most with a corresponding disappearance of the image or the production of a striking 'solarization' effect. All toned images fade in time and some are very susceptible to fading accelerated by the intense ultraviolet emission of projection equipment. It is therefore essential to look at the extreme edges of any frame to see if any less faded or altered toning or dye can be seen and never to assume that a tone is unaltered. Prussian Blue seems to fade patchily, sometimes vanishing entirely, sometimes darkening to muddy neutral colours.

Another procedure, called loosely **mordanting** or **mordant toning**, permitted the transformation of some or all of the silver salts or silver into an insoluble salt that was almost colourless and which was capable of absorbing certain basic dyes selectively. In this way it was possible to tone an image with a much wider range of colours. A considerable range of colours was possible and some appeared very similar to tinting in that the perforated edges and highlights were stained as well, but to a lesser extent. This makes it very difficult to be certain about some effects.

A great colour range was possible using **colour development**, a process later used to develop primary colours in true colour film.

In all toning processes the final image is a dye or coloured salt and some remaining silver image. Several manuals produced in the 1920s describe a technique for the removal of the silver image leaving just the coloured image behind. The procedure consisted of fixing the film in a conventional fix solution (of sodium thiosulphate). There seems no good reason why this should have worked, as silver is only sparingly soluble in fix solutions. In practice the bleaching effect is quite dramatic and may rely on some residual ferricyanide salts unwashed from the emulsion forming a powerful silver bleach or solvent known to photographers as Farmer's Reducer. Prussian Blue, copper and uranium tones, and mordant dye tones were probably often intensified by this technique.

It is possible to carry out all these procedures today using modern black and white print stocks but it is by no means certain that the colours and contrasts generated are the same as those that were produced with the film stocks, developers and sources of chemicals originally.

Occasionally a toning technique was used for colouring an entire film. *Good Earth* in 1937 was toned an overall brown using mordant dye tone used in a 'modern' developing machine at MGM laboratories in Los Angeles. The film was 12 000 ft long, of 14 reels, and 500 prints were made and toned, a total of 6 000 000 ft, probably taking about 2000 hours just to tone!

The following methods can all be used today.

17.5.1 Metallic and inorganic toning procedures – sepia toning

Sepia toning is one of the oldest methods used for toning black and white paper prints and was widely used for toning professionally produced portraits at the time that the motion picture industry was developing at the turn of the century. Also lantern slides were frequently sepia toned, although whether this was to improve their stability to strong carbon arc light sources or to produce a warmer brown image is not clear. Silver sulphide, the image resulting from toning, was certainly more stable than a poorly washed conventional silver image.

The procedure uses two wet solution stages:

1. **Bleaching**: a solution of potassium ferricyanide (20 g), and potassium bromide (5 g) in 1 litre of water was used to bleach the silver image back to silver bromide. At 20°C this usually takes about 3 minutes. This is followed by a wash in running water at 20°C for about 3 minutes.
2. **Sulphiding**: a solution of 5 g per litre of sodium sulphide was used to convert the silver bromide to silver sulphide. Silver sulphide is normally dark brown or black but, perhaps due to other reactions taking place or to impurities, the image is often a strong red–brown. The process is easily carried out using modern release stock but is unpleasant and unsafe unless great care

is taken to prevent the formation of hydrogen sulphide gas, which is readily produced if the sulphide solution becomes acid. Attention to safety precautions is essential and the process should only be done in areas of good extraction. Hydrogen sulphide is toxic and its concentration in the air must be kept at levels lower than the current TLV. The process takes about 2 minutes and is usually followed by a water wash of about 5 minutes.

The procedure was originally carried out in large tanks with the film wound round wooden racks holding from 100 to 300 ft of film. It would be possible to carry out the procedure in a modern processor provided that the tanks were made of rigid PVC, or titanium, and no iron was present anywhere in the equipment. Prussian Blue staining occurs where ferricyanide bleaches are used in conjunction with iron parts and this was a common problem in the past. Tanks were made of ceramics to avoid the problem. However, since it requires about nine different processes to produce a similar result to most original films it is rarely practical to convert a processing machine to tint or tone, and instead, batch processing using rolls of film in short lengths in small tanks is more realistic.

Sepia or sulphide toning must be carried out as a two-stage process with washing between and after. Sometimes a 'clearing' stage to eliminate some of the hydrogen sulphide released was inserted halfway through the last wash. This was a dilute potassium permanganate solution.

Many of the other metallic toning processes could be carried out in two stages – a bleach as before followed by the toning solution containing the metal salt to replace the silver, or, more commonly, in a single solution consisting of potassium ferricyanide and the replacement salt in a suitable solution. The results are not quite the same in each case, either in terms of colour or chemical composition. The single solutions are not as stable or long-lasting as two separate solutions with a rinse or wash between them. Some of the single solutions probably could not be kept for more than a few hours. However, although the textbooks and manufacturers' manuals list both, sometimes as alternatives, sometimes as recommendations, it is not really known which were used most. Probably most toning was done in batches using single solutions discarded after use, so that a long life was not required. Most of the manuals of the 1920s imply that single solution toning was almost universal.

17.5.2 Prussian Blue toning

Prussian Blue toning was very commonly used and was probably almost always carried out in a single solution. The silver image is converted to a mixture of silver ferrocyanide, which is colourless or white (but does have some density to light) and ferric ferrocyanide or Prussian Blue. Prussian Blue, when fresh, is a strong blue but seems to fade slowly in time. It also is susceptible to fading, sometimes entirely, with the effect of ultraviolet light from projector lamps.

Two separate solutions, one of 1–2 g per litre of potassium ferricyanide with 2 ml per litre of concentrated sulphuric acid, the other of 1–2 g per litre of ferrous ammonium sulphate or citrate with 2 ml per litre of sulphuric acid, were mixed in equal proportions immediately before use and the positive film placed in it. When the process had continued to the extent the operator wanted, the film was removed and washed, sometimes in a dilute hydrochloric acid to help remove the yellow stain also produced.

The whole process was critical in many ways. If the original print still retained some fixing salts the process would not work at all or only patchily. If stopped before completion then some silver image remained and the image was a dark 'navy' blue. If washing was not sufficient the base retained a yellow stain. It was also known that if washing was too long the strong blue colour could be washed out.

It is possible that the yellow base stain (which often fades to pink in time) was actually required as part of the effect or that the examples seen today of what we consider is a Prussian Blue tone on a pink tinted base is actually a Prussian Blue tone with insufficient washing fading in time from yellow to pink!

Prussian Blue, ferric ferrocyanide, is a blue–cyan in colour, and close to the subtractive primary cyan, and in the 1930s was used as primary colour for several two- and three-colour processes. During this period more stable solutions were used which lasted longer and did not stain the emulsion so much. A typical example consisted of ammonium persulphate, ferric alum and oxalic acid as well as potassium ferricyanide.

Oxalates were used in the 1920s Prussian Blue toning processes, presumably to increase stability.

17.5.3 Uranium nitrate toning (orange–red tone)

The orange–red tone resulting from replacing some of the silver image by uranium ferrocyanide was commonly used in the early years (and, like Prussian Blue, was improved to yield a primary dye for several experimental two-colour processes in the 1920s and became a common two-colour primary in the 1930s). The single solution most commonly used seems to have been uranyl nitrate with potassium ferricyanide (about 2–4 g per litre each, acidified by hydrochloric acid) and were probably stored in separate solutions to be mixed just before use like the Prussian Blue. Later formulations contained oxalates and alums and kept better.

Modern materials seem to respond less well to this procedure and the colour is less saturated than old examples even after 50 or 60 years.

As will be seen below, uranium toning was also used as a starting point for some dye toning procedures.

17.5.4 Copper toning

A red tone, more a strong red brown, was produced by generating, in exactly the same way, copper ferrocyanide using copper sulphate and potassium ferricyanide. The old examples of this tone in manufacturers' example sheets are now very faded and seem just a warm neutral. It is possible that the original effects of this tone were very unlike the results we see today. Modern materials tone well by this method but we have no way of knowing whether the effect is the same as in the early years of the century.

Copper toning was recommended in early manuals, but by about 1922 copper toning seems to be replaced by uranium toning. The resulting colours were much the same but copper toning seems to leave the emulsion much softer and more liable to damage. This is true of modern print stocks – copper toning creates a nice clear warm brown image but the emulsion is very soft and easily marked.

17.5.5 Dye toning procedures

Dye toning is a term used for a wide range of procedures in which the original silver image is replaced by a coloured dye image, or is supplemented by dyes in addition to the silver. A look at any early textbook will show that a very wide range of techniques could be used, some of which are listed below. All are possible today using modern black and white print stocks as the starting point but, as with the metallic or inorganic toning methods described above, it is not definitely possible to be sure that the tones, hues and contrasts are the same as were produced with the old print stocks.

All these techniques can be used today.

17.6 MORDANT DYE TONING

Mordant toning is a procedure based on the principle that certain organic dyes do not stain gelatine normally but will stain gelatine already impregnated with insoluble mordant compounds. The principle is similar to that of dyeing fabrics such as wool or other similar staples. There appear to have been several different routes that would not have resulted in the same visual effect even when the same dye was used. The most commonly used mordant in photography is an insoluble metal ferrocyanide, but thiocyanates and halides (especially iodides) were also used in a two-stage process.

17.6.1 Two-stage dye mordanting

The first stage is to convert the silver image to the mordant salt and the second to dye the salt. One method converted the silver image to silver ferrocyanide (Method One below) and another, apparently widely used in the

USA, as it was recommended by Eastman Kodak, was to partially uranium tone using the single solution uranium toning process mentioned above before dyeing. Iodine solutions were also used.

Method One

1. Processed print film was immersed in a 'mordant bath', sometimes called a 'mordant bleach bath', consisting of an aqueous acid solution of potassium ferricyanide that converted the silver image to white silver ferrocyanide. A typical formula was:

   Potassium ferricyanide 2 g per litre
   Acetic acid (glacial) 5 ml per litre

   Alternative procedures were to use bleach solutions that converted the silver image to silver thiocyanate, using a copper thiocyanate bleach, or to silver iodide, using an iodide/iodine bleach.
2. The film is then washed in water and dyed in a solution of basic dye. The result is a clear transparent dye image, with an additional slightly opaque image of the residual mordant salt.

Method Two

1. Processed print film was immersed in uranium nitrate toner solution as described above for about 2 minutes by which time the image had faded to a light brown.
2. The film was briefly washed before being dyed in the dye solution. Apparently this was a very effective process that gave good results without too much loss in contrast.

Needless to say, trying to identify which method was used, not to say which dye was used, is extremely difficult. Several early textbooks give lists of dyes suitable for mordant toning and paper prints were still being toned using this method until at least 1950.

In the Crabtree and Ives toning method the print is dyed in a single solution in an acetic acid/10% acetone solution containing the mordanting agent potassium ferricyanide and a basic dye. It is difficult to be sure how

Table 17.4 Basic dyes used for mordant dye toning

Dye	*Concentration (g/l)*	*Colour*	*Manufacturer*
Auramine	4	Yellow	Du Pont
Basic Fuchsin	2	Red	no data
Benzyl Violet	2	Violet	no data
Chrysoidine 3R	2	Orange	National Aniline
Chrysoidine Brown	2	Brown	no data
Chrysoidine Y Base	2	Orange	National Aniline
Malachite Green	2	Green	no data
Methyl Violet	2	Violet	no data
Methylene Blue	2	Blue	no data
Methylene Green	2	Green	no data
Neophosphine	2	Red	no data
Pink B	12	Pink	National Aniline
Rhodamine	2	Red	National Aniline
Rhodamine B	4	Magenta	National Aniline
Safranin 6B	2	Magenta	National Aniline
Safranin A	2	Red	National Aniline
Safranin Base	1	Red	National Aniline
Tannin Heliotrope	2	Magenta	National Aniline
Thioflavin	2	Yellow	General Dyestuffs
ThioflavineT	2	Yellow	General Dyestuffs
Thionine Blue	2	Blue	no data
Victoria Green	4	Green	National Aniline

common this process was, although it is widely mentioned in the literature.

In dye toning the image areas tone first and the process is 'time critical' – the longer the film is left in the dye solution the more the highlight areas fill with dye, so test strips were used to estimate the time needed. Contrast is also controllable by concentration of the dyes – solution of high concentrations dye more quickly but produce higher contrasts.

A wide range of colours are possible and Table 17.4 shows some of those known to be used in the USA and in Europe in the late 1920s.

Dye toning processes were the basis of some stencil processes that were experimented with in the 1920s but did not succeed in becoming commercially successful. The silver image can be bleached out using fix solution but the image left is usually too thin to be of use.

17.6.2 Other toning techniques

Numerous other techniques have been used since the 1850s to tone colour papers and lantern slide plates and all these must have been tried on motion picture film at some time, even if only to be rejected.

- **Replacing the silver image with another metal salt.**
- **Nickel toning** (nickel ferrocyanide) produces a wide range of reds, bluish-greens and violets depending on the solutions used, but they are unpredictable and rather fugitive and this may be why nickel was not common.
- **Lead toning** (yellow), **cobalt** (green) and **vanadium** (green) are all ferrocyanides and use the same approach but do not seem to have been used.
- **Gold toning** (blue–black) used a process of 'plating' the existing silver image with gold using a gold chloride solution. This is not found in motion pictures.
- **Selenium toning** (red–brown), hypo-alum toning (brown, but very simply done with a stable cheap solution), both seem to be restricted to paper prints.
- **Colour development toning:** this procedure was the form of colour development finally used by Kodak to produce the first reversal colour tripack film, Kodachrome, in 1935, and is the basis of all modern colour film systems. The technology of dye development by this procedure was already well documented and in the 1920s some films had already been 'toned' by this process. Much later, in the 1960s, *Moby Dick*, made on Technicolor, was probably the last full-length film to be 'toned'. A black printer was used to produce a desaturated dull effect like a dirty painting. Short films and sections made on conventional negative–positive colour film have also been desaturated. In this case the normal colour print process was modified to omit the bleach stage so that all the dyes were developed but the silver image **not** removed, giving the image an overall sombre appearance.

17.7 DOUBLE TONING

Several of the early publications mention double toning, as a partial toning with a metal tone followed by a second tone in either another metal tone bath or a dye mordant tone. One method recommended by Eastman Kodak (1922) was to partially blue tone to Prussian Blue and after a few minutes to remove the film, wash briefly and immerse in Safranin dye solution. The result would be a blue tone in the shadows and mid-tones and pink highlight tones. This could be the very common blue/pink effect seen frequently in European films of this period, although most effects of this sort were the double effects described below.

17.8 OTHER DOUBLE EFFECTS – COMBINATIONS OF TONING AND TINTING

A combination of toning and tinting was used quite often. Scenes that were already toned were then tinted, or alternatively, toning was applied to a film printed on a coloured base. The result is an image in which darks and lights are coloured in two different colours.

Perhaps the commonest double effect was probably the Prussian Blue (Iron-tone Blue) tone tinted yellow, red or pink. It is by no means certain how all these effects were done and probably there were many recipes that could have produced this effect. The appearance is both unnatural and fascinating – a toned Prussian Blue combined with a tint in orange or pink produces a beautiful sunset at sea and yet it was used for many scenes especially, it seemed, to heighten the dramatic effect. In Hitchcock's *The Lodger*, made in 1926, the exterior scenes were toned with Prussian Blue and tinted with a yellow to produce an effect similar to that of the old London pea-soup fogs, the 'London particular', the scenes were intended to represent, while the interiors, largely of lamplit rooms and theatre dressing rooms at night, were tinted by the yellow alone.

17.9 COLOURED SILVER IMAGES

Today's print film emulsions processed in a modern developer formula such as Kodak D19 produce a neutral grey image. However, the film emulsions and developer formulae used prior to 1930 all appear to produce 'warmer', slightly brown images, which can only be copied on a modern film stock by using an old formula developer process, which commercial laboratories are unhappy to use as modern customers prefer cold neutrals. Very little investigation of this aspect of archive film restoration has occurred. It is one reason why quality checking of restored images is difficult – it is almost impossible to judge the accuracy of a restoration when the image colours of the original and the restoration are different.

Some developing agents produced markedly warm brown image colours, partly because of the developing agent decomposition products laid down with the silver, and partly because the different granular dispersal of the silver image alters the colour of the image.

One technique widely used on paper was to used developing agents, such as chloroquinol, that produce naturally brown tones (in this case, due to insoluble oxidation products laid down with the silver image). The images obtained by this method may be slightly coloured by reflected light, and are therefore very suitable for paper prints, but the image is generally opaque and appears neutral by transmitted light.

17.10 IDENTIFICATION OF A TONING TECHNIQUE

It is frequently difficult to be certain what method was used to tone a print unless some means of analysing the image material is used. Small particles can be removed and in some cases of metallic toning conventional inorganic qualitative analysis can be used to identify the metal. In other cases only spectral absorption can be used and as yet there has been very little research done to enable comparative studies to be used for identification. No doubt eventually there will exist a relatively simple and cheap method. In the meantime if we really need to know, it is possible using mass spectroscopy.

17.11 TONING IN COLOUR FILMS

An important source of information on toning are the various manufacturers' manuals produced during the 1920s. However, some of the much later publications, such as Cornwell-Clyne (1951), must be used with care, as much of this data uses the term 'toning' while referring to genuine colour film not coloured monochrome print film. During the 1930s toning techniques became sophisticated and were used to tone one side of a double-coated film one colour, and the other side, another. These were not coloured monochrome films of the type discussed in this chapter, but were two-colour (and later three-colour) film prints made from colour separation negatives. These are dealt with in Chapter 18 on the restoration of natural colour film. The colours used for these had to approximate to the two-colour primaries of blue–green (Prussian Blue was frequently used) and orange–red, or the three colour primaries of cyan, magenta and yellow. Mordant dye toning and colour development as well as wash-off imbibition toning techniques were all tried.

17.12 THE DUPLICATION OF EARLY COLOURED FILMS

Restoration of coloured monochrome films was, until only a few years ago, carried out almost exclusively by conventional black and white duplication and the colours were simply recorded in writing. Little attempt was made to reproduce the original colours for archival storage or for display. Those colour restorations that were attempted were done by making a colour internegative on whatever current Eastman Colour Internegative film was available. The earliest attempts were usually poor and of too high a contrast, but today a very close visual match to the archive original can be achieved. The resulting colour print represents the colours left in the film today after whatever fading has occurred.

17.12.1 Duplication of hand and stencil coloured films

In the case of stencilled films and other systems in which discrete patches of colour are used, the use of colour internegatives is really the only photographic method possible, and achieving a better representation of the original in its pristine form can only be done by using enhancement of video signals and re-transferring back to film. These digital techniques are not covered in this book.

The procedure for reproducing a copy of a coloured print is exactly the same as for any print duplication using an integral tripack such as Eastman Colour Internegative film, and is covered in Chapter 18 on the restoration of colour film.

17.12.2 Duplication of tinted and toned films

Other coloured films are less discrete in their colour and either the entire frame was suffused with one colour (tinting), or the image was coloured a single colour (toning), or a combination of the two techniques was used. In these cases a wider range of techniques for restoration exists.

Copying the original onto colour film

The original coloured film can be copied onto **Eastman Colour Internegative** and the resulting colour negative printed onto a modern colour print stock. The results, provided the duplication sensitometry has been rigorously followed, can be excellent as a record of the coloured image now. Some limited grading can 'improve' some colours but these changes are very restricted and are largely to produce improved saturation. For example, a red tint can be made a little redder or more saturated by grading to a redder balance.

The other obvious disadvantages are cost of the colour stock, and the problems of storing colour negatives.

The duplication set-up can be done using the LAD system provided that the internegative material is used and processed in the standard Kodak specified manner, and this is dealt with in detail in Chapter 15 on duplication.

Some laboratories reduce the development time of the internegative by just a few per cent in order to reduce the overall contrast and this can produce good results. If the process time is reduced by more than about 10% the three sensitive layers no longer develop to the same contrast and an unpleasant 'cross contrast' effect occurs. Attempting to increase the development by more than about 10% produces similar cross-contrast effects. Commonly, this results in prints with a different colour cast in the shadows to the highlights; red shadows, cyan–blue highlights in particular. Once a cross-contrast negative has been produced a good print is unobtainable, and only electronic digital techniques will correct the mismatched colour.

A further problem of departing from the standard process procedure is that the LAD system, which relies on a standardized characteristic curve to allow a fixed aim density to define the correct exposure conditions, may no longer apply, and the old two-point set-up will be needed to cope with a non-standard shaped curve. Rarely is all this effort really worth while unless the laboratory is confident of spending the time (and the money).

Printing a black and white duplicate negative onto colour print stock

Any black and white duplicate negative can be printed onto a conventional **modern colour print film** to achieve an image of almost any colour (achieved by varying the grading with filters or light valve settings) from a neutral black or grey, to any saturated primary. This does make it possible to achieve quite good matches with many of the tone colours that were available.

However, by this method it is not possible to copy satisfactorily tinted films or double toned or tinted and toned films. If the image is printed somewhat dark an effect not unlike tinting can be achieved but the image loses much of its aesthetic value. The overexposure has the effect of producing hazy monochromes and the results obtained from this method are simply not of high enough contrast and the high densities are not black but simply a denser colour. Occasionally good results are obtained but the effect is best with blues and day-for-night shots, and other colours are very difficult to achieve.

There is no doubt that in certain circumstances where a film is entirely toned in a variety of strong colours, especially if the colours were produced by colour development or by mordanting, this simple and inexpensive method is very effective.

17.13 THE 'DESMETCOLOR METHOD'

This system, devised by Noel Desmet of the Royal Belgian Film Archive, has been used since the 1970s to try to restore some of the strong colours and dramatic effects of early tinted and toned prints. It is not intended to match the colours of a particular print but provide an extensive palette from which to choose colours in the same way that producers chose the effects they wanted originally. Many early coloured films were duplicated to make a normal black and white duplicate negative and notes kept of the original colour before the decaying nitrate print was destroyed. Desmet's method enables these colours to be put back as tints or tones or as a combination using the archive duplicate negatives as a starting point. The colours do not match exactly the originals, although if enough trial and error time is spent quite close matches are probably possible. The overall dramatic effect is probably very close to that of the original. A number of laboratories use this method. The final print is on a colour print film.

Working independently, Dominic Case in Australia has used a similar system but making the **monochrome duplicate negative** on **Eastman Colour Internegative**. This method was published in the *SMPTE Journal* in 1987. The choice of material was probably influenced by the idea that a masked negative material would make a more stable starting point than a black and white negative. Comparisons of the two methods suggest that the results are very similar but the use of a black and white negative material results in finer grain on the final print.

17.14 DIGITAL FILM–TAPE–FILM TRANSFER

Transfer of the monochrome image, from a duplicate negative, or a print, to a **digital electronic image** allows the image to be coloured or a suffusion of a single colour to be applied. The resulting subjectively manipulated image can then be transferred back to film via a film scanner. This procedure has not been used for archive work yet. It requires a precise specification to ensure that the image retains film characteristics, as a much wider range of parameters is also possible. Alternatively, the original coloured nitrate may be used and the colours enhanced to attempt to approach the original effect (assuming it is known).

17.15 USING THE ORIGINAL TINTING OR TONING TECHNIQUE ON MODERN PRINT STOCK

Finally, a film can be reproduced in exactly the same chemical manner that was used for the original tinting and toning. A film produced in the mid 1920s might have from three to nine different colours or colour combinations (and a maximum of 18 has been recorded).

Reproducing a film by tinting or toning in the original manner requires that the positive print be broken down into sections and each section treated separately. After tinting and toning the film is then reassembled. This is all perfectly practical but as far as the authors are aware has never been done to a long feature film since the processes ceased to be used commercially.

Most archives and some laboratories have experimented with tinting and toning using the old methods and new black and white print stocks. The results are often dramatic and tend to demonstrate that some of the colours seen in the cinema in the first 30 years were far stronger and more dazzling than at first thought, but have faded considerably. As a result of these experiments the following factors have been established:

1. Modern film stocks can still be used to carry out all the old techniques, although there is no way of being certain that the results are the same. Different manufacturers' film stocks behave differently to some dye techniques, although almost the only black and white print film available is Kodak 5302, which is very close in emulsion design to the films of the 1920s and seems to behave in similar ways.
2. Copper toning modern film stocks is sometimes unsatisfactory as the emulsion is severely softened (exactly as described in some old manuals!).
3. Uranium toning, which was used extensively as a red–brown or orange–red tone after copper ceased to be used (and as a mordant for dye toning) is impractical today. Uranyl nitrate is prohibitively expensive (about £5 per gram) and safety concerns over its toxicity and minute radioactivity have made its use difficult.
4. Many of the old dyes are no longer available but some are. Some are impractical due to toxicity or inflammability, but enough are available to repeat many of the original tints and dye tones. Some dyes can still be made to special order. However, the dyes used always did vary in concentration (and to some extent hue) and this is still true today. All the old manuals recommended testing to see what concentration was needed, and this still holds true today.
5. Tinted and toned films and all early films were originally printed, processed, coloured and then the prints cut and joined to make the release prints. In modern parlance, they were 'pos cut' not 'neg cut'. This requires that each scene be printed at least a frame longer than the final scene length as a frame was lost at each end in order to join it to the next. This requires specialized printing techniques today since all the prints and negatives available in archives are in a single roll and there is no extra frame available to be wasted. The only way out of this is to print each scene with extra frames at head and tail, or to make two prints of a film and use alternate scenes from each print for colouring.

Some tinting restoration has been done by hand brushing dyes onto the new copy, frame by frame, but this is costly, often uneven and very time-consuming. Spraying dyes from a modern spray or air brush may also be practical and will reproduce similar effects to tinting but may be unable to copy toning.

18

Restoration of natural colour film

18.1 INTRODUCTION

Some 150 different colour film systems have been devised and a number have reappeared under different names on several occasions. Fewer than this have been commercially successful. After 1950 only one general system has been commercially successful. This is the use of integral tripack films, either with the dye coupler incorporated in the emulsions (Eastman Colour, Fujicolor, Agfacolor, Gevacolor etc.), or with the dye couplers in the developer (Kodachrome, early Fujicolor etc.). The Technicolor imbibition printing method, using integral tripack negative as the camera film, lasted until 1978 in the USA and UK.

From about 1910 to 1920 'natural colour' films were rare, and many systems were demonstrated in Europe and the USA. Most used cumbersome multiple projection or rotating filters in sequence with the synthesis frames. It is not always appreciated today, but it seems that some of these demonstrations were very effective and the results were sometimes of the very highest quality. However, none represented practical solutions that could be applied to cinemas, in all their infinite variety, throughout the world.

By 1920 it was recognized, by the most realistic inventors, that the essential requirement of a commercial colour system was that the positive should be projected on a conventional unmodified 35 mm projector, and this could only be achieved with subtractive prints. Nevertheless, many bizarre and complex projection methods still made their debut, only to be almost instantly rejected as too complex, too costly or uncontrollable. A number of systems were devised that were compromises with genuine natural colour and used only two primaries instead of three. Additive mosaic systems (for example 'lenticular' Kodacolor and Dufay) made several appearances in the 1920s and 1940s, but their low screen brightness, mosaic image and complex printing made them obviously impractical.

The search for a practical colour print system was the basis of the majority of the inventions. By 1935 Technicolor Inc. had tried out a number of alternative processes, starting in 1917 (including two-colour, and all of them called Technicolor), and finally introducing the three-colour imbibition, or dye transfer print, system we think of today as Technicolor. By 1950 Technicolor was dominant in colour print production, and although the principle of the Technicolor print system was largely unchanged for 30 years, the camera films and camera techniques varied quite widely. There were competitors to Technicolor, which was not alone in the market at any time, and although, to the general public, all colour prints were thought of as Technicolor, other systems also existed, especially in the 1940s.

Some of the competition to Technicolor was two-colour film made by exposing in the camera two separation films (usually in the form of bipacks). The print was made on 'duplitized', i.e. double-coated, film toned blue–green on one side and orange–red on the other. Eastman, Agfa and DuPont made films for this process, but the laboratories gave them trade names such as Magnacolor and Cinecolor.

Technicolor prints were distributed widely after about 1936, but largely these were American or, to a lesser extent, European feature films. Technicolor imbibition prints were made in Los Angeles from 1936 to 1973, New York from 1936 to 1973, London from 1938 to 1973, Rome from 1950 to 1973. Many countries making their own films could not afford Technicolor prints, nor was it often practical to travel to a Technicolor laboratory to have one made. Technicolor was a process that was costly for the production of just a few prints and it was often said by the mid-1960s that making less than 25 prints was so expensive that any other method was to be preferred.

The negative–positive colour systems first appeared in 1935 (Agfacolor) but it was not until Eastman produced the first masked negative in the early 1950s that this system became effective. The early colour negatives, especially up to 1960, used dyes that have faded considerably and these films represent some of the most difficult material of all to restore.

In a world view colour in the cinema was very patchy until the mid 1960s. 'Natural colour' was a very rare event until 1935, whereas 'coloured' films were probably very common everywhere until 1930. From 1930 to 1935 the cinema was almost entirely black and white everywhere in the world, with just a handful of 'spectaculars' being made in the USA and Europe. From 1935 to about the mid-1960s colour gradually increased in the developed world, but only from the 1960s onwards did colour extend world wide with the advent of the negative–positive systems, especially Eastman. Although the first negative–positive incorporated couplers, colour films (Agfacolor) were on the market in 1935 it was only from about 1950 that Eastman began to dominate the colour market, and an important aspect of negative film success is the use of integral masking originating from coloured couplers.

In many major producing countries (such as India, USSR, Pakistan and Turkey) which could not afford to pay for colour film stocks in dollars or sterling, colour only became common with the advent of cheaper colour print materials from East Germany (Orwo) and the USSR (Sov) in the early 1970s. China imported the Technicolor print system in the 1970s but until that time almost all Chinese film was black and white.

Although all cinema and most television film is negative–positive, reversal colour films have played a major part in the historical changes. Kodachrome in 1936 had a major impact on 16 mm documentary and amateur use and in 35 mm was, for a while, the camera original film for Technicolor prints. The earliest Fuji colour films, 1948 to 1954, were reversal 'Kodachrome type'. Later reversal films played important roles in documentary production and news film.

18.2 CATEGORIES OF COLOUR SYSTEMS

Colour film systems fall into a number of broad categories, each of which directs the restorer to a specific approach, while a smaller number are not easily categorized.

The following are examples of the main categories – the first three used separate films to produce separation records that were synthesized in different ways. Technicolor became solely a printing method by 1955, but began life as a series of complete colour systems.

18.2.1 Kinemacolor type: two- or three-colour analysis/additive synthesis/two- or three-colour additive projection

In the silent period, most colour systems were additive. Separate records of each colour, red, green and blue, were made by exposing three separate frames through three coloured filters. When projected, each positive image (containing the information of a single colour) was projected back through the original coloured filter. On the screen an image reproducing natural colours was obtained as a result of the addition of the three colours.

In some cases, in order to simplify the process, only two colours were used (orange–red and blue–green), which resulted in an imperfect colour reproduction but was probably still quite striking in the cinema. The two-colour systems derived from this principle have mostly left us with negatives and prints in black and white. These are only recognizable due to the fact that each frame is slightly different in rendering one from the other (for example, a red flag appears to be transparent in the red frame and opaque in the green and blue ones), or from the unusual geometry of some of these inventions (in some the two separations were inversions of each other, since one was exposed through the base, and the other not).

Several different systems based on this principle were developed. Gaumont Chronochrome, developed in France by Gaumont, was a system using three different frames (red, green and blue) taken at the same time with three different lenses placed one under the other. Behind each one of the three lenses was placed a filter of the corresponding colour. The film was projected in the same way, using a projector with three lenses. Chronochrome frames were shorter than those of standard 35 mm films and had only three perforations per side.

The Kinemacolor system, developed commercially by the Englishman Charles Urban, was designed to shoot two different frames through a rotating filter that alternated between blue–green and orange. The film (standard 35 mm) ran at a speed of 32 frames per second and the rapid sequence of the pictures in the two different colours produced a plausible, even if imperfect, colour effect.

Friese-Green developed a system similar to that of the Kinemacolor, but which was based on shooting of three successive pictures through three filters.

18.2.2 Nature Colour/Cinecolor type: two-colour analysis on two separate films/two-colour subtractive print on double-coated toned film

Typically these films were exposed in a special camera designed to handle two films in the same gate, or two films exposed to the same image by a beam splitter. The two films, often sold as 'bipack' by several manufacturers, produced separation images corresponding to the different sensitivities of the films or filters used and were records of blue or blue–green and orange, the two-colour primaries. The resulting separations were printed onto double-coated or 'duplitized' (USA term) print film, one separation on each side, and the silver images toned or dyed blue–green one side and orange the other. There were innumerable variations in dyeing, film sensitivities and camera mechanisms, some of which became defined by trade names. The first use was probably about 1917 and the last about 1948! One of the early Technicolor systems fell into this category. The first Technicolor, called Technicolor bipack or bichrome, was introduced before 1920. It was based on two negatives exposed through red and green filters which were printed on two black and white films, then toned in cyan and magenta and finally glued together. This system was used in several films, starting with *The Toll of the Sea* in 1922.

18.2.3 Technicolor 1935 type: two- or three-colour analysis on one to three separate films/print by toning, dyeing or dye transfer

These all commence with separate separation records but transfer the image onto a common support by some form of image or physical dye transfer. In 1928 Technicolor abandoned one method – of two dyed positive films glued together, and transferred attention to the dye-transfer system, still as a two-colour system.

In 1932 came the Technicolor 'tripack' or 'trichrome', commencing at first with animated cartoon shorts, later with a few medium length films and finally a feature, *Becky Sharp*, by Rouben Mamoulian.

Dye-transfer is the principle of the later Technicolor, from 1935, and is very similar to the wash-off process for paper printing called Dye Transfer. From the three negatives (red, green and blue) three **matrices** are made, that is, three positives in black and white. The silver image development also tans the gelatine and prevents its wash-off in hot water. The remaining relief image absorbs cyan, magenta and yellow dye, in proportion to the original density. The dye is transferred onto a 'blank' film with each image in register.

Sequential exposure animation was a term given to exposures in a normal camera in a sequence through red, green and blue filters to produce a single strip of negative with sequential separation negatives. Once made, a subtractive print could be made by a wide range of techniques – Technicolor, onto duplitized film, Cinecolor, Gasparcolor, or onto a modern tripack colour intermediate. Many animation films were made this way, and the process is only applicable to animation. Some films were issued first in one print system and re-released later in another. (N.B. Disney pictures were always filmed on Technicolor 3-Strip.)

18.2.4 Dufay type: three-colour analysis on single film in discrete areas/additive projection via original filter mosaic or optics

Several additive systems involved the use of a mosaic (termed a réseau in Dufay) of red, green and blue filter patches on the emulsion surface or in the lens system, exposing discrete separation images relating to each patch. In Dufay the patches were lines and squares of filter on the film emulsion, in lenticular Kodacolor the lines were created from the lens system. Reversal processing and projection through the original or similar filter patches yielded a colour image not unlike colour television. Negative–positive systems existed as well, although printing was complex in order to avoid interference patterns from the filter mosaics.

18.2.5 Agfacolor/Kodachrome/Eastman Colour type: three-colour analysis on integral tripack film/subtractive synthesis on integral tripack film

The incorporated coupler colour films using an integral tripack were first put onto the market in Germany in 1935 following the release of the very first tripack, Kodachrome, in 1935. The early motion picture materials of this type were reversal. In reversal/reversal duplication or printing from colour prints, the lack of an integral mask produces colour reproduction problems beyond one stage of duplication. Fourth or fifth generation reversal duplicates are of very poor quality for this reason, whereas fourth generation duplicates using masked original and intermediate materials still return good colour quality.

Although the first colour negative was released in 1935 by Agfa, only in the late 1950s did a successful negative–positive system emerge, from Eastman Kodak. Much of the success of the Eastman system was due to the integral mask on the negative. Most other manufacturers followed the Eastman lead and Agfa, Gevaert, Fuji, Sov and Orwo all produced similar materials.

Although the dyes used in modern integral tripacks are called cyan, magenta and yellow, they are not perfect, and this leads to some problems. When one film image is duplicated onto another, the imperfections in the dyes compared with the ideal subtractive primary colours, characterized as unwanted absorptions, are duplicated, reducing the colour saturation of the final prints. As multiple generations are produced so the problems of colour saturation are increased. This problem can be partially resolved in reversal materials only by complex chemical adjustments to dye formation that takes place in development, called **interimage effects**. In negative–positive systems almost complete correction is possible in the negative stage by the use of **integral masking**.

The unwanted green and blue absorptions of the **cyan** dye image print-through onto the green- and blue-sensitive layers of the duplicating stock. This is equivalent to a small pink impurity in the cyan dye image.

The unwanted blue absorptions of the **magenta** dye image prints through onto the blue sensitive layer of the duplicating stock. This is equivalent to a small yellow impurity in the magenta dye image.

The **yellow** dye image is satisfactory and needs no change.

These impurities vary in density with the density variations of their own dye images, so producing actual print-through images in the duplicating stock.

These unwanted absorptions, the pink and yellow in the dye images, are balanced exactly with amount of pink and yellow in the unexposed parts of the emulsion. This produces an overall orange cast to the film which can be filtered out in printing.

To achieve this the colour couplers in the cyan and magenta dye layers, which are used to form the dye images in exposed and developed image areas, are themselves coloured pink and yellow respectively. Once a coupler becomes part of the dye image, it loses its own original colour.

Thus, in areas with no dye formation, there is a strong orange mask colour present, and in areas where cyan and magenta dyes form, the orange mask disappears to balance out the unwanted dye absorptions now present. The result is known as an **integral mask** and is used in all colour negative and intermediate film stocks, to retain good colour reproduction through multiple duplication stages.

Integral masking has made restoration simpler, since once a colour image is recorded on a masked film several integral masked stages of duplication can be undertaken without excessive loss of colour quality. Duplication using unmasked films loses some of the original hues and contrasts in just a single generation.

18.2.6 Integral tripack analysis/ Technicolor print type: three-colour analysis on tripack film/print by subtractive dye transfer

Technicolor was widely used as a print system until the 1970s, and in China until the 1990s. Even after the advent of Eastman Colour, the three Technicolor plants (Los Angeles, London and Rome) continued to produce positive copies; some produced from 35 mm Kodachrome, and later three matrices were made from Eastman Colour negatives.

Although Technicolor has probably been the only print system to use integral tripack film as the starting point, any of the previous printing systems, from duplitized toned film to Gasparcolor, could do the same.

Technicolor was primarily a cheap production method for printing, but the copies of the later films confuse archivists with credits that say ‘Print by Technicolor’ and also ‘Made in Eastman Colour’ and finally it is better to inspect the film and establish from its material exactly how it was made.

Code marks of almost all manufacturers of colour film can be found on the edges of Technicolor film copies: Kodak, Ferrari, Agfa, Gevaert, DuPont etc. These indications refer to the manufacturers of the black and white film or blank film that was used for the production of the Technicolor prints and not to the colour system.

18.2.7 ‘Dye destruction’ colour printing systems

Gasparcolor was one of several ‘dye destruction’ direct positive printing systems that used a tripack film with three layers sensitive to red, green and blue that already incorporated cyan, magenta and yellow dyes. A positive image was exposed onto the film. The negative silver image produced by development was used to initiate the destruction of the coated dyes, resulting in a subtractive colour positive. Gasparcolor is not unique; there were a number of patents issued for these processes, and Cibachrome is a modern still colour paper print material. Although in theory the process could have been used for a camera original film the dyes coated in the emulsion reduce the photographic speed to very low levels.

18.3 THE PURPOSE OF COLOUR FILM RESTORATION

Restoring black and white film results in the production of a new print much like the original and the approach requires little decision making other than deciding what contrast or grading is needed to restore the original appearance. The resulting restored image is silver just as the original image was, and although modern materials do differ in response to older materials, in general there need be little difference between old images on old film stocks and new ones on new stocks.

Colour film requires more consideration, as the dyes in use today in modern subtractive colour films are, in almost every case, different from those originally used, and in some cases modern subtractive dyes cannot be used to produce a match with some of the dyes used in the past (particularly the primaries of additive processes). Almost all modern restoration techniques for archive colour film use modern film materials in a manner never used originally or ever intended by the film stock manufacturer. A good example is to consider the production today of a colour print from a set of three separation negatives made in 1940 for the production of a Technicolor print. The usual procedure is to print the separations onto black and white stock to produce a set of separation positives, print these in register through a set of tricolour (red, green and blue) filters onto Eastman Colour Intermediate film and print this masked colour negative onto modern colour print stock. The result can be very good, but may bear little resemblance to a Technicolor print. The print will be visually more like a modern tripack print than an original imbibition print. Using modern materials usually results in restorations that are a visual blend of characteristics of the old image and the new film material.

Alternative attitudes might be as follow:

1. Long-term preservation of the present image, to allow a restoration to be carried out later.
2. Make a print, a copy of the present archive image.
3. Make a restoration of the image that is a simulation of the original cinema image before the effects of time and storage.

18.4 LONG-TERM PRESERVATION OF DYE IMAGES

18.4.1 Preservation principles

If the intention is to preserve the image in a reliable permanent manner that allows later restoration, then the most effective method is to generate red, green and blue monochrome separation negatives, or positives, on a modern silver image material which are independent of the permanence of any dye images. Sometimes polyester base is used but most archives use modern acetate based film stocks. These separation images record the colour of images as they are today, after any fading that might have occurred.

If the elements available are already monochrome separations that need to be restored, then high quality monochrome duplication as described in Chapters 15 and 29 is required. Other systems have also been proposed to do this, such as the use of digital video signals, on disc or tape, but the permanence of a silver film image on a modern film base is still considered more certain than the unknown life of any video system hardware.

Many colour systems in the past included the use of black and white separations as 'protection masters', sometimes called 'PMs'. However, they are not a single consistent format or element and their contrasts depend on the originals from which they were made. PMs made from Technicolor separation camera negatives are positives of a high contrast (almost that of a conventional projection print) whereas PMs made from Eastman Colour Negatives (also positives) were of much lower contrast.

Once a set of PMs existed a printing negative or negatives could be made from them at any time. In the Technicolor process the PMs were printed onto a black and white duplicating stock to make colour separation negatives. From these the matrices used for the imbibition process could be produced.

PMs from an Eastman Colour Negative could be printed onto Eastman Colour Intermediate through tricolour red, green and blue filters in register to produce a duplicate colour negative. Once these two principle routes are established in a laboratory and set-ups exist so that they can be performed repeatably they constitute the basis of almost all colour separation restoration.

18.4.2 Copying a colour print

While identification of the process is desirable in every restoration case, there is always a need to copy a colour projection print without restoring the colour. In these circumstances it may be justifiable to make a colour copy without understanding how the process worked or what the original film looked like. It must be clearly understood that such a copy is of limited value as a record of the visual appearance if the image has changed or faded.

18.4.3 Restorations of the original image

These techniques are usually specific to the colour system involved. In many instances modern print and duplicating films can be used to make new prints from old elements. These may or may not be similar to the original images.

18.5 THE USE OF MODERN COLOUR DUPLICATING FILMS

In common with black and white archive colour film duplication relies entirely on existing commercial processes and the continuing availability of special film stocks entirely designed for modern production. Eastman Kodak devised almost all the current methods and these are described below, with their derivative techniques used for archive film restoration. The three principle techniques are:

1. Separation black and white images made as conservation images for storage or intermediates for restoration. The only available film stock is Eastman Panchromatic Separation film.
2. Eastman Colour Intermediate films, to produce duplicate negatives from existing negatives and black and white separations.
3. Eastman Colour Internegative film to make colour negatives from projection prints.

It is essential to realize that a proper set up procedure will produce the best results, but also that the exposure of any duplication film stock must be continuously monitored to ensure that the resulting density range is limited to the straight-line portion of the characteristic curve. These procedures are contained in Part 4, Chapters 35–37.

18.5.1 Black and white separations for duplicating and conserving colour negatives

In this system (widely used since its publication in 1947 by Eastman Kodak) black-and-white separation positives are made from an original colour negative. The process was a development of the many three-strip colour camera systems in use from about 1930. The master positives can be stored. If, later, they are to be reconstituted to create a new negative, they are printed in register onto a multilayer colour film to give the colour duplicate negative. This system has the advantage of providing a more or less permanent record of the valuable original because of the keeping characteristics of processed black-and-white films. Where negatives differing in size from the camera negative are required, the operation of printing in register three black-and-white positives is both difficult and expensive.

Archive laboratories use both the original commercial process and derivatives of it. The black and white film stocks used were originally designed for duplicating masked colour negatives but are also used to make separation negatives from unmasked colour negatives, colour prints, or any other colour intermediate or even a coloured nitrate film. These derivative processes are generally used to correct for faded dyes and are described later.

18.5.2 Colour intermediate film for duplicating colour negatives

The second system (first devised and published by Eastman Kodak in 1956) employs a multilayer colour film for preparation of both colour master positives and colour duplicate negatives. This procedure is much less time-consuming than the first method, also it eliminates the need for a registering-type printer. Proper removal of residual hypo and correct stabilization treatment are essential to retard changes in the dye images to ensure long keeping and so, for long-term storage, black-and-white separations should still be made for protection purposes.

Procedure

In this system, both the colour master positives and colour duplicate negatives are made on the current Eastman Colour Intermediate film.

This is an incorporated-coupler type of multilayer film containing colour couplers similar to those used in Eastman Colour Negative films. The upper, blue-sensitive layer contains a colourless coupler which is converted to yellow dye during development. A yellow filter layer prevents blue light from reaching the layers beneath. The next layer is green-sensitive and contains a yellow-coloured coupler which forms a magenta dye during development. The residual yellow-coloured coupler becomes a mask to correct for the unwanted blue absorption of the magenta dye. The bottom emulsion layer is red-sensitive and contains a pink-coloured coupler which is converted to a cyan dye during development. The residual pink coloured coupler forms a mask to correct for the unwanted blue and green absorption of the cyan dye.

Eastman Colour Intermediate film also contains absorbing dyes which prevent scattered light from travelling significant distances in the emulsion layers. By this means image sharpness is enhanced. These absorbing dyes are water-soluble and are removed from the film during processing. A removable black antihalation layer is coated on the back side of the support. When printed and processed as recommended, the effective reproduction contrast of colour intermediate film is near unity so that the contrast obtained in the duplicate negative is similar to that of the original colour negative. This is an essential feature of the film as it is designed to be used in both stages of the duplicating system.

Status M or Certified MM filters are used for the densitometry of Eastman Colour Intermediate film. The contrast of the film, as measured on a densitometer, may not be exactly 1.0 as the density values obtained will not be true printing densities due to differences between the film spectral sensitivity and the combination of filter transmission and spectral sensitivity of the photocell. Typical 'Best Fit Contrast' values for colour intermediate film, would be blue 1.02, green 1.04, red 0.93. The printing contrasts of the dye images are about equal for both specular or diffuse illumination, permitting either optical or contact printing to be done from the same duplicate negative.

Process control

Control of processing Eastman Colour Intermediate film is critical and it is necessary to adjust the development time and if necessary increase the developer agitation level, until the contrast levels are satisfactory. With low developer agitation a high blue contrast or low red contrast mismatch is likely.

Exposure of Eastman Colour Intermediate film

To ensure that Eastman Colour Negative film has optimum printing contrasts when making the first, positive, intermediate stage, and to retain optimum printing contrasts when printing the second, negative, stage, energy at both ends of the visible-light spectrum of the printer light is removed. The Kodak Wratten Filter No. 2E, which absorbs light of short visible wavelengths, in combination with an efficient heat-absorbing glass such as the Chance ON21 or Pittsburgh 2043 (4 mm thick) is optimum for this purpose and these two filters should be used in all printers and scene testers when printing onto Eastman Colour Intermediate film from dye images.

18.5.3 Colour internegatives for duplicating colour positives

The third system involves preparation of a colour internegative on a multilayer colour film from a reversal colour original. This method (from about 1952) was introduced by Kodak for the production of large numbers of release prints, and when a reversal printing system would be considered too expensive, or in places where reversal print processing facilities were not available, or for reduction. The positive material for which it was originally designed was Ektachrome Commercial, a rather low contrast camera film with a contrast of about 1.0, that was never projected. Today this film is no longer made and the aim contrast of the internegative film has been reduced a little, but it is still too high. The original material had a contrast of 0.6 and it is still about 0.5. The ideal today would be 0.4.

Colour Internegative film has become the workhorse material of the archive, as it is the only film whose contrast is in any way designed to produce a negative from a positive projection colour print. It has a fixed contrast but there are some methods for reducing the contrast, in particular flashing, but there is none that is satisfactory, for increasing the contrast.

In using any of these systems, the basic rule for making master positives (either black-and-white or colour), colour duplicate negatives and colour internegatives is the same as that applied to normal black-and-white duplicating work – namely, to use only the straight line portion of the characteristic curves of the duplicating films involved. This procedure ensures that optimum tone reproduction will be obtained; in other words, a one-to-one transfer of the tonal values of the original will be effected.

Two methods are possible for the production of internegatives.

1. A generalized procedure can be established at the internegative production stage so that all internegatives are produced at a single printer setting and grading is carried out at the final printing stage.
2. The original positive can be graded by various means so that a '**graded internegative**' can be produced. The final printing stage is then a one printer light, and therefore a high speed, operation.

The second method will produce the best results, but with this duplication route various 'hybrid' versions of the procedures can be used to produce overall quality more or less between the two alternatives.

Ideally a sensitometric control strip of the same film material as the original print film is used to print tests. This is obviously impossible if the original is an old coloured nitrate film or an extinct early colour print. After much testing it has been found that this is not all that critical and a control strip of a modern colour print film works reasonably well.

18.5.4 Colour Reversal Intermediate (CRI) film

Another system (introduced first in 1968) used to exist and made use of a colour reversal duplicating film called Eastman Reversal Intermediate film 5249. Use of such a film meant that, for making a duplicate negative, one printing/processing stage was eliminated. Reduced graininess and improved sharpness did not compensate for a very difficult material to process reliably and repeatably, and in 1993 it was discontinued. It was never extensively used for archival restoration work, however many archives will possess duplicate negatives made on this material.

Existing CRI material can be printed normally. It is thought that this film will fade considerably and the techniques for its restoration will be similar to restoration of a faded negative.

18.6 LABORATORY AIM DENSITY (LAD)

This simplified motion picture duplication control was established by Eastman Kodak in the 1970s because it was felt that most laboratories did not actually use the two-point systems shown above! As a result the quality was extremely variable, resulting in smoky shadows, blocked-in highlights, contrast mismatches and poor colour reproduction. For duplication control, many commercial laboratories used a standard scene negative made by themselves, or sometimes a 'China girl', made by a manufacturer or technical society, a density patch on a piece of negative, or just guesswork. Rarely did two laboratories use the same control system or work to the same aims. Inconsistency was, and still is, one of the biggest problems.

The 1959 Gale and Kisner two-point methods and the derivative methods based on them that are described above are undoubtedly the best method of control and are strongly recommended for critical work on archive film. Their system of duplication recommended test printings of a control strip. The print-through is used to peg the shadow and highlight densities. This two-point (also sometimes called full curve) method is still valid but many laboratories find it too time-consuming to use as a routine duplication control method so a simplified system to reduce variability and improve quality was designed and this is known as the LAD, or Laboratory Aim Density, method. It was published in full in the paper 'A simplified motion picture laboratory control method for improved colour duplication' by John A. Pytlak and Alfred W. Fleischer in the *SMPTE Journal* (Volume 85, October 1976).

The LAD Control Film provides both objective and subjective control of a duplicating procedure. The Kodak LAD Control Film is made on intermediate film, which is exposed from an original negative in a way that it prints exactly like an original camera negative. A description of the image will be found in Chapter 14. There are specification densities for the large grey patch in the LAD Control Film, which if followed throughout each printing or duplication stage will produce good tone and colour reproduction since achieving the aim density ensures that the range of densities falls on the optimum positions on the characteristic curves. These densities are listed in the tables of aim values in Chapter 34.

Proper tone reproduction can be quickly determined by visually viewing the image of the girl's head at any stage of duplication. Loss of shadow detail would be indicated by no difference between the 2.5% black patch and the adjacent unlit plush black background behind the model. Loss of highlight information would be indicated by no difference between the white patch and the 'white reference' frameline. And, of course, all six steps of the grey scale should be visible with proper tone reproduction, i.e. graduation to grey from white to black, with little or no colour shift.

18.7 SPECIALIZED METHODS – FADED DYES

All dyes used in photography fade with time. Many of the dyes selected for early additive filters are reasonably stable but those dyes developed in some way during processing fade to considerable extents. The dyes used for toning, Prussian Blue, uranium ferrocyanide and the basic dyes used for the two-colour processes like Cinecolor, and the numerous duplitized print processes, all fade too. Prussian Blue and perhaps uranium ferrocyanide are unusual in that they do not fade to colourless but darken and desaturate towards neutral grey or black, making the image darker than the original (see below).

18.7.1 Incorporated coupler tripack dyes

All dyes fade in time but some are far more prone to fading than others. Many magenta dyes used in integral tripack films are azomethines and are very stable, whereas many yellows and cyans fade easily. The degree of fading of integral tripack dyes is directly related to the original quantity present and generally the dyes fade to colourless rather than change colour. The visual effect is therefore to reduce the maximum density of the fading dye and reduce its visual contrast resulting in a change in colour balance and the effect known as crossed curves. Many films go magenta as the magenta dye is least or not at all affected.

This proportional fading provides possible mechanisms for correcting the effect. It is helpful to find out the degree of fading in a film. This can be done with a densitometer providing there is in existence a piece of unfaded film of the same stock and period. You should select images of maximum density and compare the R, G, B densities on the assumption that the faded film originally had similar maxima to the unfaded. This technique is useful and easy to apply to some faded prints of the 1960s and 1970s since fading of this period is often due to poor stabilizer formaldehyde concentrations and therefore unfaded, well processed film of the same period is usually easy to locate.

In the case of many print films that are pale and strongly visually magenta, another opportunity for measuring the degree of fading exists. It can be assumed that the magenta has not faded at all (this is never absolutely true but still useful as a premise).

Select a maximum density area and measure the Status A values. It can be assumed that the original densities were more or less equal or visually neutral. In the above case the percentage fading of a cyan dye can be calculated from the formula

$$\% \text{ fading of cyan dye} = \frac{D_{\text{green}} - D_{\text{red}}}{D_{\text{green}}} \times 100$$

18.7.2 Other dyes

The effect of fading tripack dyes is rather different from the fading of metallic toning dyes of early toned films, and two-colour duplitized films. Some, the metallic ferrocyanide dyes, became denser or less saturated or altered hue with time, often in a patchy, uneven way, and fading may be dependant on

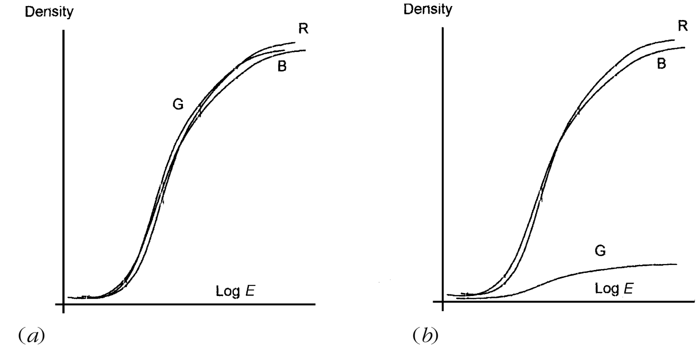


Figure 18.1
(*a*) Characteristic curve of an unfaded colour print film.
(*b*) Characteristic curve of a print film with faded magenta dye

ultraviolet light from projection. No percentage fading measurements are really useful in these instances. It is usually necessary to make an internegative or separations that do not have a record of the patchy or uneven dye. Often this is not possible, but some films can be recorded onto black and white for subsequent reproduction by using a filter to eliminate or reduce the unevenness in the duplicate image. The filter should be selected by trial and error but it should be of the same or similar colour to the dye colour, and the film recorded on panchromatic film stock.

18.7.3 Chemical methods of 'restoring' faded tripack dyes

These processes were regularly recommended in the past and there is some literature relating to the theory, but the practice is exceptionally difficult. The Editor [P.R.] has experimented with the techniques but, not surprisingly, has never been permitted to carry out the processes on real archival film of any value by an archive! The processes generally work but they cannot be recommended since they are impossible to control, and it is not possible to know the long-term effect of the procedures on the film treated. The following methods are summarized for interest but are not advised.

One chemical process is to reconstruct the original dyes from the breakdown products that still remain in the emulsion by 're-processing' film in various solutions. Cyan dyes seem to respond to this chemical process but yellows are not so responsive. All the formulae for the tests carried out by the Editor were from verbal sources! Some of the past literature mentions that manufacturers publish chemical formulae for this procedure but none is known to the present authors and certainly Eastman Kodak do not recommend this. In any case, specialized solutions are difficult to handle and need to be located in a processing machine in order to treat long lengths of cine film.

The only procedure that can be in any way recommended is to re-process faded film in a modern process similar to that originally used – a negative process using CD3 (e.g. ECN2) for a faded negative film – a print process using CD2 (e.g. ECP2) for a faded print. The temperatures should be reduced to about 25°C to avoid excessive emulsion softening. There is some unpredictable beneficial effect on faded cyan dyes of old Eastman and Gevaert colour print films but little effect on faded negative film.

A more effective, but drastic, chemical treatment of faded print film is to intentionally destroy a proportion of the magenta dye until a low contrast but more neutral image is achieved. Azomethine magenta dyes are very stable but are susceptible to acids. The film can be held in a 3% (about 1 N) sulphuric acid solution for up to 3 hours during which time the magenta dye diminishes. Once treated until the balance is about right, the film contrast is now too low and must be copied onto a high contrast internegative film to restore a print of the original contrast. This method does work – however it is messy, very difficult to carry out on a long film length, can damage processing machinery and can be uneven in effect. It also seriously softens the film emulsion and it is a race against time to achieve the right degree of magenta fading before the emulsion falls off. This is also not recommended.

18.7.4 Faded dyes – photographic masking methods

A mask is a separate image that can be combined, in register, with the original image in order to produce a modified image. The technique has been extensively used in restoring still photographs, and was also used for the correction of unwanted dye absorbtions in preparing prints from colour photographs in the graphic arts industries. The old Dye Transfer, Carbro and Vivex paper colour printing systems all used masking wherever the original was a colour transparency. The technique will provide excellent correction for faded dyes but is extremely difficult to apply to small images repeatedly. The process entails printing the original to make a mask image and combining the original and the mask or masks, in register, to then print.

Making a mask

In order to reduce the problems of 'fringing' caused by a mask not being perfectly in register with the original image, masks are usually made slightly unsharp. Since contact printing is almost universal in order to make the image exactly the same size, the mask is usually exposed through the base of the original. Masks may be made on black and white or colour stock, negative or positive, depending on the purpose of the mask.

This procedure is extremely difficult on any printer, and is generally only done on a step contact printer. Printing on an optical printer is possible only if the printer has been specially designed for this. Rotary contact printers are also difficult, although this is more commonly done in order to produce subtitles and the degree of slip and imprecision makes registration very imprecise.

An extra set of supply and take-up spools and a drive are needed to supply and rewind the mask roll which will usually be the same length as the original roll.

Masks are usually used for two procedures. The first is **to combine with an original during the printing of a separation negative or positive**. In this case the mask is used to produce a separation image that matches the other two separation images in contrast. The process is used for the restoration of faded negatives or positives where one dye is more faded that the others. The mask is made on black and white panchromatic film by printing the original with colour light of the colour to be restored. A faded cyan dye on a negative requires a black and white mask made through a red filter. The resulting positive mask is printed to make a negative mask and the mask and the original combined in register to make the corrected red separation positive.

This process is extremely rarely performed; it is costly, time-consuming and requires a technician capable of matching the resulting separation contrasts. Considerable technical understanding of the process is essential to calculate the process gammas required. This makes the procedure one that will only be carried out as a last resort in organizations that specialize in colour film restoration. This process can correct faded colour film when one or more dyes are virtually undetectable to the eye. Similar but less correction can also be produced by varying the development contrast of the separation image. This is explained in the chapter on colour duplication (Chapter 17).

The second procedure is **to combine with the original when printing a colour internegative or intermediate**. In this case the mask can be black and white in order to correct contrast (an unwieldy technique almost never used since flashing or development control is easier) or a coloured mask in order to correct for faded dyes. This last technique was a very effective and relatively simple procedure that has not been carried out for some years. Two techniques are described by C. Bradley Hunt in 'Corrective reproduction of faded motion picture prints', in the *SMPTE Journal* (July 1981). One is very complex, the other relatively easy.

In the **flashed dupe mask method** a positive print of a faded original (usually a positive) is made on a colour reversal print film to a colour balance and contrast more or less complementary to the faded image. For example, a faded colour print is often magenta due to the fading of the yellow and cyan. The mask would be visually green in this case, with a low green contrast, produced by flashing the print film. When combined in register the three contrasts can be equalized, and the process is easy to control without sophisticated sensitometry since the combined mask and original will appear neutral, or 'correct' in balance when the mask is correct. From the combination of the mask and the original a colour internegative or intermediate can be made.

This procedure is easy to operate, although making the mask may need some trial-and-error printing. Dyes can be corrected when the contrast reduction is up to 30%.

The process is hardly used today because the majority of the need is to restore 35 mm and 35 mm reversal processes do not exist in commercial laboratories. The technique could be used for 16 mm restoration (for example of faded news film) but has not been used so far.

The **dupe mask method** is more complex but can correct up to 50% dye fading.

Separation methods from coloured originals – three-colour subtractive films

The procedure for making separation positives from colour negatives has already been described, and the procedure is similar when making separation negatives from positives.

The same sensitometric control calculations apply. The technique can be adapted to a wide range of restorations provided the original characters of the colour process are known. The usual reason for making any separation during a restoration process is in order to correct for fading. If fading has not occurred or a copy of a film image is required in its present condition separations are an unnecessary process.

Separations are still, however, considered the best method of preserving a coloured image, because the black and white image has a longer life than any colour image. However, the quality of many separations was not very good. Contrasts often do not match, registration is not good and storage sometimes results in separations having different shrinkages. Separations were made as insurance against damage to the original camera film but were rarely used and even more rarely checked to see if they could be used.

18.8 SPECIALIZED METHODS – THE PROBLEM OF MISSING SEPARATION RECORDS

In some processes prints of separations were made for permanent safe keeping. In Technicolor PMs – protection masters – made from camera original separations were made in case the original was damaged. A separation was rarely lost, but in the Technicolor process, perhaps other processes, the green negative was used to make monochrome, black and white, prints and was occasionally lost or damaged and was often more scratched than the other separation. Sometimes one separation was removed from storage on its own, just for a grader to check something, and never returned, or returned to a new location and lost. So occasionally a laboratory is called on to make a new print or a modern colour negative from just two separations.

Usually a third separation must be made or invented – a neutral, balanced positive can never be produced from two separation records using just two conventional subtractive dyes.

A reasonable result can sometimes be made by using two-colour primaries, as the two-colour systems. This is particularly effective if the blue record is lost. The red record is exposed through a red/orange primary filter, and the green through a green/cyan primary filter. Both Kodak (Wratten) and Lee make filters of this character.

If a green record is lost a surprisingly good final result can be made by producing a new separation from a combined, i.e. a contact overlay, of the other two! Presumably this is due to the fact that green is the brightest colour visually and combining the other two approaches the relative brightness of neutral colours. Combining the other two works less well in other cases. Using one separation for two-colour exposures works to some extent if the green is used to make a blue record also at a lower final print exposure. Needless to say, although it is usually possible to achieve neutral greys and so the overall print appears 'correct' or 'to balance', some or many colours may be inaccurate!

Loss of the red separation is the most serious, resulting in the least acceptable result.

18.9 SPECIALIZED METHODS: SEPARATION METHODS FROM COLOURED ORIGINALS – TWO-COLOUR SUBTRACTIVE FILMS

Subtractive two-colour films (Cinecolor, BI-packs and DuPacks etc.) of the period from 1920 to 1950 pose a special problem. They are generally metallic colourants or basic mordant dyes, quite unlike incorporated coupler colour films, and some fade by darkening and/or changing colour. This poses real problems if it is not known what the original primary colours were or looked like.

Some restorers have ignored this aspect and make three RGB separations from which an intermediate colour negative (on Eastman Colour Intermediate) can be made. This copies the faded original, using modern three-colour technology, but allows some variation in saturation to be made by varying the contrast of the final colour print. As the forensic study of early colour films improves the original colours of these two-colour primaries will be known – where they are, they are considerably more saturated than originally believed – and better methods will become available.

One technique that has only been used a

few times is to make two separations to record just the two original dyes. These separations are then printed one after the other (like A rolls and B rolls) onto modern colour print film each exposed to produce a colour corresponding to the original two colour primaries. This is a extension of the Desmetcolor method used for simulating tinting and toning.

18.10 SPECIALIZED METHODS: SIMULATIONS FROM ADDITIVE MOSAIC SYSTEMS

The additive processes are most difficult to simulate or to copy, and retain the screen character of the original. The Dufay process images, reversal originals or negative–positives using a réseau of red, green and blue areas each providing a tiny separation record of that part of the scene, are very difficult to copy. The dyes appear to be reasonably stable and seem not to have faded in up to 60 years. Eastman Internegative is often used to make a colour internegative and thence a colour print. The result is usually disappointing to anyone who has seen an original projected. The originals, even Dufay prints from Dufay negative, are dark and of a very low screen brightness but very saturated. Modern subtractive dyes have difficulty in achieving the high saturations of the original réseau, and perhaps all subtractive systems, *per se*, will have this problem. Certainly a modern telecine unit can translate a Dufay image into a far better video representation of the original than any film.

The best approach for all mosaic or lenticular additive colour systems is to copy them onto reversal print film stock such as 16 mm Ektachrome Print. The higher than usual contrast compensates for some of the lost saturation and the black areas have a higher density than colour print film.

Many mosaic and lenticular and ruled screen systems were used to make documentary film of relatively important events in the 1920s and early 1930s and probably were quite dramatic records of those events in their original format. Some were copied to make more easily distributed versions, onto whatever 'colour' system was available, with the result that archives contain some extremely confusing prints. British Realita ruled screen film, and Dufay was printed onto two-colour print film such as DuPont Duplicoat or Eastman Duplitized film or onto Kodachrome Print film, even onto Technicolor, with the result that the original is almost unrecognizable.

In the British Pathé collection newsreels were made from many film origins and important images reused in later issues. Sometimes the edge printing comes through. Raycol, an early screen system, can be read on the edge of a two-colour print coated with orange dye on one side and blue–cyan on the other and a bright blue, variable density, sound track (presumably therefore a Cinecolor print or similar). Dufay can be seen on the edge of an early unmasked Gevacolor negative. More often the origin is simply obscure, and some are so unsharp that the image of the réseau or ruled lines has been lost.

18.11 SPECIALIZED METHODS: SIMULATIONS OF ADDITIVE PROJECTION SYSTEMS

The most difficult simulations to achieve are the early additive projection systems that are now often restored by printing onto modern colour print film via modern colour negatives or intermediates. The originals were either three separate projectors, or the sequential projection of three separate images through red, green or blue filters, or were two records treated in this manner.

The filters were either over the camera lens or were dyes applied to the film, by conventional tinting. Very few technicians or archivists have ever seen original material projected this way, although, in principle, it is not difficult to do. The early colour filters were at least as good as those produced today – the modern Kodak Wratten tricolour filters used for the original photography as well as for the projection, Wratten 25, 58 and 47B, are the same today as those made in 1910.

A modern additive system can be produced along similar lines to Kinemacolor or the sequential frame systems. A still additive colour image is very easy. Three still negatives are made of a scene, on panchromatic film, through the three tricolour filters, and three prints are made. These are projected in register on a single screen from three projectors each with the relevant filter put over the lens. The relative projector brightnesses may need adjusting using neutral density filters, but providing the contrasts of the three separations are similar a very high quality colour record is produced. This suggests that the primary problem of early additive colour was not the quality of the image but the complexity of the equipment needed to project synchronously and in register the three images. In the case of sequential images this had to be done at three times the normal projection speed to reduce the flicker.

Unfortunately many modern simulations lack the colour quality that must have been present originally, probably due to several different effects:

1. Sequential frame systems were often tinted frames and these dyes fade – copying on modern colour internegative film simply copies the faded colours.
2. Red, green and blue filter primaries were very saturated and even ideal subtractive dyes cannot encompass these saturations.
3. Subtractive dyes used in modern films have notably poor cyans which are darker and less saturated than they should be and magentas that are darker and bluer than they should be.
4. Our expectation of the quality of these early films is probably low, and we fail to recognize the degree of correction we need to apply.

19

Restoration of film sound

19.1 SOUND ELEMENTS IN ARCHIVES

A range of different sound elements are held in film archives. These vary from the original sound records, to the final theatrical print track with the sound synchronous with the action. Early discs, cylinders, and various drawn tracks are the subject of specialist restoration. The most common elements used throughout the cinema and television world since 1930 are sound tracks on the print film adjacent to the image.

From about 1930 until the 1950s, and later in some parts of the world, sound was recorded directly onto photographic film as an optical track, using an **optical film recorder**, sometimes called a **sound camera**. This device produced a recording as a variable density track or a variable area track, in the normal Academy sound track position on a separate 35 mm black and white film. Recording on 16 mm film was rare and perhaps extremely rare.

There were many different cameras in use. Each produced a slightly different and recognizable image within the standard area. The film used in these cameras was a fast blue, later orthochromatic, film called Sound Recording film, and Kodak and Agfa have together dominated this market from the 1930s to today. The film was processed in a conventional negative developer and produced a high contrast image in the case of the variable area film and a lower contrast for the variable density. Today no variable density tracks are made principally because the quality was lower but also because the stocks made for this system are no longer made. Therefore all restorations are almost always remade as variable area restoration whether they started that way or not.

19.1.1 Optical sound negatives – SEPOPT

Once the film image was edited a single optical track negative was made by combining all the various tracks, sound effects, speech, music etc. This process was called dubbing and for many years all speech was recorded after the editing in a dubbing suite synchronously with the image. Today sound is recorded as the image is shot and synchronized at the rushes stage, remaining synchronized thereafter. SEPOPT stands for Separate Optical (track).

Variable area tracks

A sound track is divided into two areas, a transparent area and a dark area with uniform regular photographic density.

High frequencies are shown on the track by sharp serrated curves that may partially or completely disappear under the effect of image spread or increased graininess due to printing. The phenomenon of image spreading is mostly noticeable with sibilant human voice sounds (s, ch, t ...) and is due to scatter of light in the emulsion, and scatter the recording system.

The light that exposes the film in the sound recorder must have a controlled degree of spread while providing a maximum difference of density between dark and clear areas of the track.

The image spread is particularly disturbing on high frequencies where the gaps between the valleys and peaks of the recording are rather narrow. Valleys are partly filled, producing a distortion of modulation and consequently of the sound. To avoid this the intensity of the exposure lamp should be considerably lowered. The problem is that

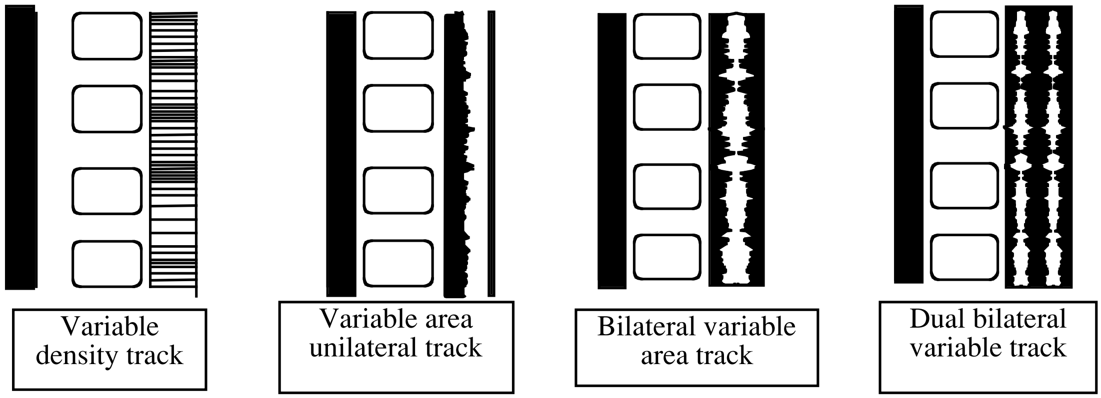


Figure 19.1 The four most frequent negative sound tracks found today. Only the bilateral track is in wide use today, and this is being replaced by modern digital track formats

doing so the density would be insufficient, producing weak sound. Experiments showed that it was necessary to allow some spreading of the image during negative exposure. Such a negative does not fit as the sharp modulation valleys are partly filled. The same phenomenon occurring during the printing of the positive compensates for the negative phenomenon. Therefore it is possible to set negative densities that, balancing with positive density, permit an exact sound to be obtained without distortions.

Cross-modulation tests are used to measure the distortions and calculate the best exposure levels that provide optimum distortion cancellation.

Cross-modulation tests

For high quality recording and reproduction, the print must have the highest possible density to give a high signal to noise ratio, a high level (difference between opacity and transparency), and a low distortion. For a variable-area recording, the print density should be approximately 1.5 for satisfactory reproduction (this number is given by stock manufacturers). At this density, after development of the positive, the image spread fills the valleys of modulation and retains sharp modulation. This non-symmetry is caused by the high density required, and produces a distorted signal in this negative image.

The image spread in the negative is compensated in the image spread in the positive print. The cross-modulation test is used with variable-area recordings to determine the correct negative exposure by measuring the degree of image spread in the valleys of the modulations. In Figure 19.2 you can see the recording slit. In A there is less light than around the point B. This exposure produces an image outside the image area producing a low density in the filling. On development, a distorted negative signal is produced.

When this negative is printed onto a positive film, the images in the valleys, now the peaks of the modulations, produce a compensation effect. This exposure is managed and selected by the cross-modulation test to produce the most symmetrical signal.

Cross-mdulation signals are recorded at the end of each reel of a film to check the distortion of the printing. Because of the different routines followed, a sound negative is not necessarily compensated for by the routine print exposure in all laboratories, so tests are needed to establish the best print exposure to produce the most symmetrical track with the least distortion.

In modern production a cross-modulation test exposure is retained at the head or end of each reel to facilitate this process when the negative changes laboratory or the laboratory changes its print stocks. In some countries these cross-modulation images have been used for the past 30 years or more, and may be found on negatives in archives.

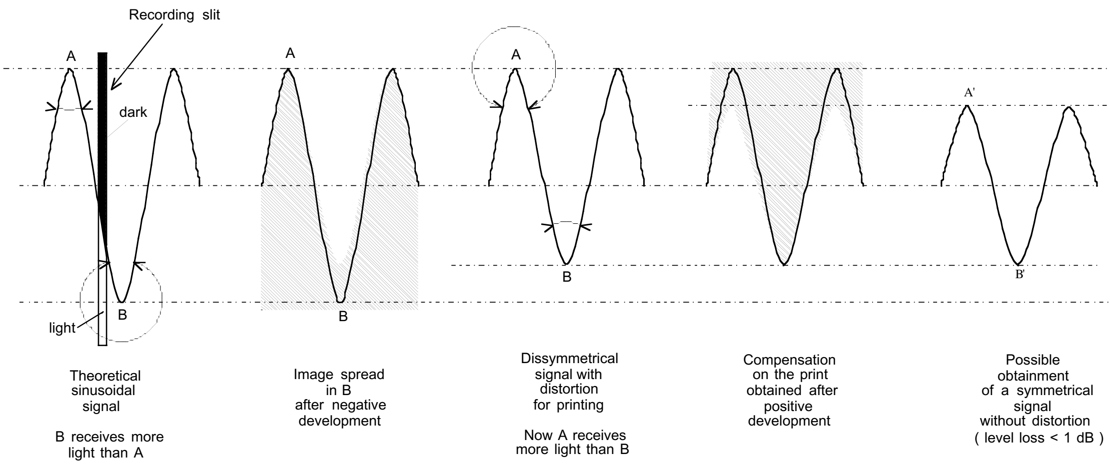


Figure 19.2 Image spread and cancellation on variable sound

Variable density

Variable density optical sound tracks are no longer produced. Here the problem of distortion is slightly different.

The best results are obtained by using the straight line section of the characteristic curve of the print film in order to retain the comparable relationships between the different densities. The exposure onto this section of the curve requires precise settings of the exposure.

Contrast is very important in variable density tracks and the relationship between the negative and positive films is generally held to be:

$$\gamma N \times \gamma P = 1$$

where γN stands for sound negative contrast (gamma) and γP stands for sound positive contrast. This is the Contrast Rule mentioned elsewhere in this book.

In general, the print contrast was usually 2.0 to 2.5, and the development of the negative track was therefore to 0.5–0.6.

A similar test to the cross-modulation test was used with variable-density recording to determine negative and positive densities, called the '**intermodulation test**', rarely carried out nowadays.

Variable density tracks are no longer used. The best method of preserving and restoring them is to preserve the tracks in variable area formats:

1. Transfer print sound tracks by re-recording to make new variable area negatives.
2. Print negatives to make modern new prints and re-record to make new variable area negatives.

19.1.2 Combined prints – optical – COMOPT

The separate picture negative, now cut in sequence as a single length, and often called in English-speaking laboratories the '**mute**', is printed onto the print film to create the 'combined' print. The sound track negative, often just called **track**, is printed onto the sound track position of the same print film, either by a second printer or, since the 1940s, on the same printer but in a special sound track printer gate, usually placed before the image gate. The sound track is always a fixed number of frames in advance of the picture to allow the two projector 'heads', for picture and sound, to be separated. The image is always projected intermittently, and the sound track is always scanned by the sound photocell continuously. The sound cells responded to infrared light principally. An incandescent lamp projects an image of the sound track onto the photocell. Just as a print from a picture negative is positive so a print from a sound negative is reversed in its tones. COMOPT stands for Combined Optical (track).

19.1.3 Identifying optical sound tracks

Dating a print film by its optical sound track is not at all easy. There are a number of easily recognized systems but the recorders were in use over many years and since they were scanned by a standard projector sound track head many minor systems stayed in use for many years. In the 1980s at least five different systems were still in use. The change to digital sound tracks and to stereo sound tracks has standardized the sound track image appearance. There were a few locally used or limited use systems which are immediately recognizable and therefore easy to date.

Much easier to date are the variable density sound tracks used by early colour processes. Whereas all variable area tracks are silver images, with dye where the film is colour, the early two- and three-colour films used variously coloured variable density tracks with and without silver. Cinecolor use a Prussian Blue track with no silver, and Dascolor probably used Fuchsin (orange–red). Optical tracks are used on 35 mm and 16 mm film and for a while even on Super 8.

19.1.4 Combined duplicates – COMOPT

Most theatrical release film prints were and still are made from duplicate negatives. The duplicate negative is made with a sound track negative transferred onto the sound track position, and made from a combined master positive. Both picture and track can be printed at a single gate on a continuous rotary contact printer, and the aperture needs to be wide enough to do this. This technique is used for both black and white and colour.

19.1.5 Magnetic sound tracks various formats – separate music and effects

During the 1950s magnetic recording replaced optical recording during the shooting and dubbing process and the final optical negative was then made only after the final mix and dub was completed on tape. Numerous formats existed, first based around the same perforated film formats of 35 mm and 16 mm until the 1970s, when first came reel to reel 'quarter inch tape', then cassettes of various sorts and finally, now, DAT (digital audio tape).

The perforated tapes were designed to be used on 'double headed' projectors or synchronized 'followers' that ensured the picture and sound synchronization during the mixing and dubbing. Once the final mixed track was made, usually also on a perforated magnetic film, the final sound negative was made in an Optical Sound Recorder.

19.1.6 Double-headed formats – SEPMAG

Television in the 1960s through to the 1980s used a specialized system throughout much of the world. Since no conventional projection system was needed the film images were made as mute films, i.e. with no sound track. The final sound track was made on perforated magnetic film and 'followed' on a special playout unit when the film was transferred to video on a telecine. When these films were viewed by a live audience, which was quite common, they were viewed on 'double headed' projectors that ran both elements synchronized.

SEPMAG is a term meaning Separate Magnetic (track).

19.1.7 Combined originals – COMMAG

When the print has a magnetic track in the optical track position the projector must be fitted with a magnetic pickup head. This has a different advance from the optical track so that a projector can be fitted with both heads. This was very common on 16 mm from 1950s to the mid-1980s to cope with colour reversal news film that was pre-striped with a magnetic track and sound was recorded in camera (e.g. Ektachrome EF and VNF films). Processing had little effect on the sound, but the magnetic track is a catalyst for the vinegar syndrome (see Chapter 23) and these films are among the worst effected.

Magnetic tracks were and are also used on 35 mm and 70 mm print films since it allows multiple tracks to be held on the one film.

COMMAG is a term meaning Combined Magnetic (track).

19.2 RESTORING THE SOUND TO THE PICTURE

19.2.1 From original film elements – printing and making combined duplicate negatives

Original sound track negatives can be used to make duplicate sound track negatives by the identical process of making a duplicate black and white picture negative, via a master positive, using the same sensitometric criteria.

A good method if the original negative is in a reasonable condition is to make a new combined master positive and a duplicate negative. This may require a printer with the usual rotary contact sound gate that can handle shrunken film, or has a special sprocket pitch or has worn sprockets.

If this is not possible a print on normal black and white print film may be made and the sound re-recorded as below.

19.2.2 From prints – re-recording

The full original sound quality can only be reproduced from a print, since some of the errors incorporated in the preparation of the negative track are compensated for (called cancellation) by equivalent effects in the print film. For this reason it is common to record the sound from a print on a conventional quality projector and re-record this using an Optical Sound Recorder in order to produce a sound track new negative. If the print is in reasonable condition this is the best, indeed the only, practical route. A sound negative can be played on a projector, and produce sound of the same frequencies, but since there has been no cancellation the sound is distorted, and since the density is not as high as the print, the levels may not be correct. However, if the film is shrunk many projectors and most specialist optical sound followers which have very tight sprocket tolerances cannot drive the film successfully. There are some capstan drive followers made for this purpose but these have other limitations, particularly slippage when film is buckled or is uneven.

19.2.3 From prints – photographic copying

The last option in the case of shrunken film is to make a new sound negative from a print sound track by optical printing. Fine Grain Duplicating Negative film is used and the exposure and contrast controlled to achieve a density equal to a sound negative of that period. Since there are few sound followers that are capable of handling very shrunk film and printers are generally more able, this method has its advocates and can achieve good results within limits. A rotary contact printer must be used.

19.2.4 Synchronizing

When optical tracks or perforated magnetic tracks are matched to film images the only technical synchronizing problem is where frames have been lost (or sound track lost) due to damage or recutting, and the decisions needed then are reconstructional and ethical. However, serious synchronization problems occur with reel to reel and cassettes, which have no perforations, and where shrinkage has occurred in the film and/or the tape. These problems are becoming more common as vinegar syndrome affects more recent acetate films. There are several routes to correct this: once it is certain no frames are lost the recording may be stretched or compressed in time by varying the speed of the magnetic 'follower'/player used to playout to the Optical Film Recorder. Alternatively, digital restoration is needed.

19.3 Restoring sound quality

Once a sound track from an old print, or from a print made as a restoration of an old negative track has been re-recorded onto magnetic tape (usually DAT is used as the format) the sound character can be adjusted and defects can be removed. Two principle methods are used for this.

19.3.1 'Sweetening' or 'mixing'

The relative values of the different frequencies may be adjusted to provide a more acceptable effect. This process is similar to the modern process of mixing sound tracks during post-production stages of film making, using filters and tone controls. Extreme sibilance and some of the high frequencies due to scratches and poor recording can be adjusted by these simple tone controls.

19.3.2 Digital sound restoration

For some years now a range of digital software has been available for the adjustment of sound quality in modern film production, and these are easily adapted for archive sound control and restoration. Using either automatic correction or a visual method that displays the waveform of the sound all sorts of effects can be removed or modified. Clicks and bangs due to poor recording or damage can be removed, tonal range and relationships can be adjusted and lost sections can be replaced with other sound from other parts of the track or with other sound from elsewhere. The most widely used softwares are No Noise from Sonic Solutions, and the various Protools versions.

20

Video images and digital restoration of archival film

20.1 TRANSFER OF ARCHIVE FILM IMAGES TO VIDEO

Non-broadcast and broadcast standard video transfers are made for television release and research access. Small local archives and now national archives are increasingly unable to find the funds to preserve all their film in the original formats and make broadcast standard access copies as their only version, other than the original, of some material.

Although many archives and commercial video facility houses transfer archive film to digital tape formats, they use routine, conventional commercial equipment and techniques.

Film images can be recorded, manipulated and transferred to broadcast or non-broadcast formats in real time, that is, at the same speed as the film takes to project. The image produced is much lower in resolution than the original film in most instances. Additive screen processes, some small gauges and film duplicates that have been copied many times are sometimes so low in resolution that a broadcast standard video reproduction loses little or no data.

The process of transfer to a video signal is carried out in a telecine machine, generally manufactured to handle modern film and with controls designed for the grading and manipulation of modern film stocks.

20.1.1 Telecine (TK) film transport

Systems vary, but today almost all have continuous motion, not intermittent, the frame scanning being carried out on the continuously moving image. This, coincidentally, makes it easy to handle most shrunken film securely, and most are able to transport film very gently even when rewinding or searching.

Speeds of up to 1000 ft/min are sometimes used for this shuttling process and these speeds can be reached within a few seconds from stationary without undue risk. As TK units use fewer driven sprocket rollers, often only one, almost all can handle a far greater range of film shrinkage than any optical intermittent printer without changing the drive. Some makes, however, are better than others. A Rank Cintel telecine tested at Soho Images in London proved able to handle shrinkages up to 2.8% without serious unsteadiness or film damage, although some splices in severely shrunken film caused the film to jump out of rack.

20.1.2 Splices

No TK unit can handle shrunken film with sharp alterations in ‘stiffness’, such as produced by some splices, especially where the overlap of film is far more than used today. Some early splices were 5 mm wide or more. These wide splices are especially common in some of the very early ‘pos cut’ film, and are also sometimes found in early cut negative film of the 1930s.

When these splices pass over the drive sprocket they cause a slight jump in the progression, enough to cause the automatic frame data to consider that the film has jumped a perforation and the image ‘goes out of rack’ by one perforation. Extra pressure on this roller can prevent this, but this is normally only applied on a rerun when it has been seen to occur. The only alternative is to cut out and replace the splice as a butt tape splice (to avoid losing this frame). Severe shrinkage accentuates the problem.

If this is not corrected the problem is seen on tape replay as a 'roll'. The image jumps out of rack and the operator immediately corrects it manually back into rack. This can almost always be corrected if required, although it is the most common fault seen in archival film transfers, and is sometimes left to be removed by editing the tape, although this will add to the cost.

20.1.3 Use of xy zoom, and framing

The zoom or variable magnification control is essential in order to compensate for some serious shrinkage. The zoom is most used to select the area of the original frame to be seen within the TV format of 4×3 (1.33:1) or the wide screen format of 9×16 (1.77:1). Academy and the standard 16 mm frame lose no image on 4×3 but almost all other frames will need some loss or a black bar at top or bottom (or both) to handle greater aspect ratios. An archive must specify exactly how any AR other than 1.33:1 is to be transferred.

A common problem occurs with silent frame material badly copied/restored onto film on a sound aperture printer. The image covers the frame from frame line to frame line but the sound position is cut off down one side. In English newsreel collections this problem dates from the reuse of silent newsreel images in sound newsreels!

20.1.4 Phase reversal

TK units can transfer the image as a positive from a positive print, or as a positive from a negative (known as phase reversal). The image quality from phase reversal is largely dependent on the grading or the initial set-up of the unit, and the picture quality from negatives or duplicate negatives is usually quite as good as from prints.

20.1.5 Sound tracks

Any sound track can be handled provided the right accessories are available. All, or almost all, TK units have optical and magnetic sound heads and can read conventional COMOPT and COMMAG tracks and are at least as good as projectors in this respect.

Separate tracks need 'followers' – these are play units for magnetic or optical tracks that are linked to, and can be synchronized to, the TK unit.

Many stock shot and newsreel companies still retain their film as negative and optical negative tracks, and these are the most difficult to handle as negative tracks do not have the distortion 'cancellation' that has occurred during the printing of a positive track. Some followers are able to cope with this with a special 'cancellation' circuit but in almost every case the sound quality, and sometimes level is better from a print.

Optical sound track negative films shrink in the same way as image films but often to a greater extent than the corresponding image film and as optical followers use large diameter sprocket wheels they are more susceptible to shrinkage problems and risk of damage than any telecine. Some optical followers can be laced to use a shorter sequence of sprockets than usual, some cannot! Sometimes the only solution is to print the optical track onto a print stock and use the positive track.

20.1.6 Grading

The longer it takes a telecine operator to grade a film the longer it takes to transfer any film to video tape and the greater the cost. Most transfer companies charge by the operational hour for telecine use. They do not price per metre (or foot) like a film processing laboratory because the different film gauges have different running times.

16 mm film at 24 fps runs at 36 ft (10.97 m) per minute. 16 mm film at 16 fps runs at 24 ft (7.3 m) per minute. 35 mm runs at 90 (27.4 m) and 60 ft (18.3 m) per minute respectively. The term T-factor is used to describe the ratio of running time to transfer time. The lowest T-factor is about 1.25, where 1 hour of film running time takes 1 hour 15 minutes to transfer. The lower the T-factor the lower the cost. Difficult negatives that need to be graded at every scene may require T-factors of 4 or more.

The better the condition the film is in the faster the transfer. The films need to be checked for splice damage and splice weakness, as if they were to be printed, but telecine machines do not usually need to have the perforations present on both sides. Tests on the telecine are essential to reduce the risk of over repair of the film which increases the cost and effort.

A telecine operator is trained to continually maintain a constant and consistent signal and therefore can make continual small adjustments to level and gamma (and colour). This is called grading-on-the-fly or continuous grading. If there are few big changes or the film is a graded print these small alterations are hardly visible. A T-factor of 1.25–1.5 would then be realistic.

If this is not required, and it is not usually for the transfer of archive prints or for any negative, then a specification of the grading method must be agreed with the operator.

One-light grading (T-factor about 1.25) is where a single grading setting is used throughout a transfer. This is only of use in transferring modern rushes film to video and should not be used for archive transfer purpose.

A common grading method is one-light per story or set-up. This is suitable for grading newsreel prints and many other graded prints. T-factor will be about 1.5.

Grading can be carried out by rehearsal programming the changes to occur at cued positions (called edits), usually at scene changes, followed by a transfer run. This is often called 'pre-programmed grading' and there are several variations.

A fine grade is where time is taken to perfect a well graded result by grading every scene. This is the method for grading original negatives to produce a high quality master. The T-factors will vary from 3 to 6.

A best light transfer is where the grading provides a full range transfer of all the data, usually slightly compressed to a lower than perfect contrast in order to allow a subsequent fine grade done at a tape to tape editing workstation. T-factor is usually about 3.

The best light term is occasionally used (incorrectly) to mean a faster grade than a fine grade but better than a one-light per set-up.

The best policy is to agree a T factor with the transfer company as this will determine the time and the cost. A graded print will require a T-factor of about 1.75 and an unguarded cut negative a T-factor of about 2.5 to obtain a good result. More time needs to be added for archive film due to the occasional frame 'roll'. For a major broadcast release a fine grade will be needed if the original is a cut negative.

Grading on the fly takes least time, costs least and produces the least consistent result and is not suitable for unguarded negative material. It is not advisable for any archive material unless cost of transfer is the prime concern.

20.1.7 Noise reduction

Most TK units have some form of 'noise' reduction that reduces the visual appearance of grain or electronic noise. Control of this is largely subjective and too much use can result in an image that loses its film appearance. Too much noise reduction of a grainy image can reduce the visual sharpness and the image becomes 'fuzzy'. In all probability no noise reduction is preferable to a lot; however, very old nitrate negatives are often very dense and some noise reduction produces a better visual appearance. These devices are sometimes called Digital Video Noise Reducers or DVNRs.

20.1.8 Scratch, sparkle and dirt suppression

Many TK units have, as an accessory, some form of scratch or sparkle elimination programme. The technique is based on the recognition of images that are present at that position only in a single frame (sparkle or dirt) and vertical 'tramline' images of a particular character (scratches) that are present in the same position in every frame of a sequence. A frame store can be used to replace these pixels with images from preceding frames (in the case of dirt and sparkle) or adjacent luminance (in the case of scratches). This occurs at real time as the transfer progresses. Most programmes can vary the degree of sensitivity and replacement and the best level in found by rehearsal. Too much correction can result in essential image or fast moving action being lost, such as footballs or sheep in the distance!

20.2 DIGITAL RESTORATION OF ARCHIVE FILM

Over the past 15 years digital television technology has become a routine technique for the production of special effects for television commercials and television programmes. For 30 years the technique of transferring the television image to film has been improving from the early and very primitive 'telerecordings'. These two technologies have been slowly coming together for many years, and form the basis of most modern cinema special effects and could become a basis for restoring archive film.

Digital television made it possible to copy and transfer television images many times without corruption, which had not been possible with analogue signals. Specialized software can be used to combine and manipulate the images, to edit programmes and to produce effects.

Film scanning is the process of transferring a film image to digital video signals, which can then be used for conventional television transmission, for corruption-free duplication, or for special effects. Initially all scanning was at broadcast quality, 525 or 625 lines and recorded 720 pixels (individual picture cell elements) across the width of the image. High definition television (HDTV) uses a larger number of pixels per line, and a corresponding increase in the number of lines. The highest resolutions used today are about 4000 pixels per line across a full aperture image and this approximately corresponds to the maximum resolution of modern negative colour film.

The earliest equipment for 're-recording' a television image onto film consisted of a cine camera with the frame change mechanism coordinated with the scanning of the television tube it photographed. This method still exists, in far more sophisticated versions, and is joined by laser film recorders and electron beam recorders.

Initially, when television images at conventional 525 and 625 lines were transferred to film the line structure was always visible in the film image. Line doubling and other techniques were developed as a method of reducing this effect, and today, even images recorded from conventional television signals need not show any line structure. Today most cinema commercials are produced at broadcast quality and transferred to film with line doubling, and the audience is rarely aware these are different from a feature film image made directly from film.

Once scanning and re-recording could be carried out at high resolutions, special effects and titles could be made for the cinema by this route. These are still a little more costly to make than by photographic, so called 'optical' or 'photochemical' methods, but are more flexible, and are becoming faster and less costly as time goes by. The range and complexity of digital effects far exceeds optical effects.

The earliest digital image software allowed replacement or reconstruction of local sections of image and therefore allowed film defects such as damage, scratches, marks and dust to be 'retouched'. This was and still is widely used for disguising film defects on video, and is also used to repair film defects at high resolution by re-recording back to film. The process avoids re-shooting damaged film and may be paid for by insurance companies.

The procedures used for 'retouching' are mostly manual and rely on an operator with considerable manual dexterity. However, automatic methods that can restore dust and damage marks, and some scratches, are in use and are being improved.

20.2.1 The digital film restoration sequence

Digital restoration of film follows a sequence of scanning a film image to make a digital video record, manipulating the image to restore damage or non-original characters using a specific software at a work station, rendering the new digital image, and re-recording the video data back onto film.

The film image
→ film scanner
→ digital image store
→ workstation
→ digital image store
→ film recorder
→ film

The film used is always negative, black and white or colour, and a print is made by conventional printing. The process is slow and costly but can generate modified images of great precision. Until to the time of writing (late 1990s) the process has only been used for films that have a significant commercial value once restored or modified, such as the Disney animated feature films of the 1930s the 1960s Fantomas series in France, 'Easy Rider' and so on. In every instance (?) only segments of films have been restored and never (so far as the present authors are aware) an entire feature film. National film archives have not so far afforded the process in general, although the Swedish Film Archive has commissioned work.

20.2.2 The dilemma for film archives

A few archives (for example the Swedish Film Archive) consider that they have now safely preserved by transfer to modern stocks every restorable film in their collection, and are now left with just the really difficult but invaluable material that could not reasonably be restored by photographic methods. Those in that apparently happy position now have to wait for technology to provide a new approach to their problems, nearly all of which fall into the following categories:

1. faded colour films where no unfaded element remains;
2. cases of serious physical damage;
3. films in which the defects, such as scratches and marks, are printed from previously damaged elements;
4. films that exist only as two- or three-colour separations which are difficult to re-register.

The rest of the archive world are in much deeper trouble. They simply cannot copy their existing collection quickly enough. Even if money were no object, some film archives are so large that there are no local laboratories capable of transferring the quantity of film, nitrate or acetate, onto modern film stocks before nitrate decay or acetate vinegar syndrome overtakes it. The National Film and Television Archive in the United Kingdom is about to undertake the task of inspecting its huge acetate collection with funds from the National Lottery, but will not be able to preserve by duplication more than a fraction of the most decayed material. Many archives in Europe are envious of even this.

Cost is the major problem, forcing archives to consider these and the following other options.

1. Separating the collections into material where the image is the prime consideration, and which could be kept as video quality tape for access, and other film, where the image and the format are relevant, and where photographic image resolution is important. This is contrary to the principles of the International Federation of Film Archives (FIAF) but to some archives seems inevitable.
2. Considering non-photographic or photograhic image storage at various quality levels, from video equivalence up to 35 mm film projection resolution for the entire collection. This has centred the discussion on 'digital masters', but the exact nature of this master is problematic – conventional video standards, analogue or digital have a poor record for archival permanence.

Departing from film, if only for some of an archives' collection, means an increasing dependence on equipment, as video records and digital masters need equipment to translate them to images. In television the life of a video record is only as long as the life of the playing equipment, and considerably less than any film system, and changing the archival storage format from time to time seems inevitable for television images.

On a current practical level, a digital master at video resolution (720 pixels/line by 625 lines) is a small box with three hours of programme. At 35 mm film resolution (4000 pixels/line by 3000 lines) it is a store-room full of many black boxes costing £0.5 m and holding only 40 minutes!

Finally, it does not seem that digital restoration offers any benefits to archives other than enabling them to restore film that they could not otherwise restore. The cost is far higher than transfer to digital broadcast video or conventional photochemical methods.

20.2.3 The resolution of films

Eastman Kodak tells us that a modern 35 mm Academy colour negative film frame requires a

Table 20.1 Resolutions in pixels

Scanning system	*Max. resolution of area available (pixels)*	*Resolution at 1.75:1 (height × width pixels; actual values)*	*Total pixels (millions)*
Cineon normal frame	3112×4096	2304×4096	9.44
Cineon Vistavision scan	6224×4096	6224×4096	25.49
Klone Scanner	3072×4096	2300×4096	9.42
Spirit scanning,	1440×1920	1080×1920	2.07
Photo-CD	2048×3072	1728×3072	5.31
EC Square pixels/Eureka	1526×2048	1152×2048	2.4
Common Image Format/Sony, SMPTE	1080×1920	1080×1920	2.07
ATRC US 1050 high def. proposal	960×1440	960×1440	1.38
MIT/AT&T US proposal	1024×1280	720×1280	0.92
CDI	560×768	432×768	0.33
CCIR 601/EC 625 line	576×720	432×720	0.31
CCIR 601/US 525 line	486×720	365×720	0.26
VGA, Word processor screen	480×640	360×640	0.23
VHS (approximation)	328×438	246×438	0.11

resolution of 4000 pixels resolved horizontally across the frame in the video image recording system to retain all the image data present, and this is borne out by experiment. However, it is also true that a 2000 pixels per line film image appears to be visually little different from a 4000 pixels per line image in most cinemas. Table 20.1 lists some of the resolutions of existing standard items of equipment. The broadcast standard of 720 pixels across the horizontal is clearly in a different category to the resolution needed for a film image.

Older film stocks may need lower resolutions to retain all their image data. The best resolution needed for any specific film type is largely a matter of guesswork and experiment. So little work has been done on early film that it is impossible to allocate an optimum resolution to a film material. Surprisingly good results can be seen regularly in cinemas showing images derived from broadcast quality D1 and transferred to film on a Lightning, Solitaire or Celco film recorder after processing the signal through a ‘line doubling’ (sometimes called ‘enhancement’) process. These images have an equivalent resolution of about 1400 pixels per line. Most viewers are unaware of the difference in resolution between these and the main feature.

The following is no more than a series of guesses arrived at by discussion with experienced technicians (who probably will disown their estimates!) at the sort of resolution needed to store all the data on various film materials or systems. Only time will tell if these are relevant – no easy method exists for deriving the resolution needed from an archival film frame.

20.2.4 Bit depth

Bit depth is the term used to describe the number of units to record tones or brightnesses of image across the available range from black to white. The term only relates to digital units: 2 bits would be 4 tones; 3 bits, 8 tones; 4 bits, 16 tones; 5 bits, 32 tones; 6 bits, 64 tones; 7 bits, 128 tones; 8 bits, 256 tones; 9 bits, 512 tones; 10 bits, 1028 tones; 11 bits, 2056 tones; 12 bits, 4128 tones. Clearly the more the better; low bit depth images look like posters with only a few tones, but the greater the bit depth the more digital memory needed to store the data. All scanning and re-recording today is at 8 bits or more, although above 10 it is not always possible to see a difference.

20.2.5 Scanning film

Most modern broadcast standard digital telecine machinery is continuous motion capstan friction drive and can handle more severely shrunken film than any unmodified

Table 20.2 Resolution requirements in pixels: estimates from discussions

Film system and frame size	*Resolution required? (height × width pixels; approximations)*	*Total pixels (millions)*
35 mm Eastman Colour Academy frame 1997	2057×3656	7.52
35 mm Eastman Colour full frame 1997	2664×3656	9.74
35 mm Eastman Colour Vistavision 1997	3456×6144	21.23
35 mm Technicolor print Academy frame 1950	1000×1750	1.75
35 mm Black & white nitrate negative Academy 1935	2057×3656	7.52
35 mm Black & white nitrate print Academy 1935	2057×3656	7.52
35 mm Black & white nitrate negative full frame 1920	1140×2000	2.28
35 mm Black & white nitrate negative full frame 1915	1140×2000	2.28
35 mm Prussian Blue toned full frame 1925	761×1354	1.03
35 mm Cinecolor (2-colour) print Academy 1940	1000×1750	1.75
16 mm Eastman Colour frame 1997	900×1575	1.4
16 mm Ektachrome EF news film	761×1354	1.03
16 mm Eastman Colour print 1960	761×1354	1.03

printer. In practice, telecine operators are generally unused to correcting archive film and need retraining, otherwise they use whatever technology is on their desk to create a result as close to a modern image as they can. This may not be serious in black and white film but is ethically unsound, and certainly not wanted for early colour and coloured film. Telecine operations need new set-up procedures for these films and especially for tinted and toned material. A telecine operator meeting a combined tinted and toned print for the first time is quite unable to proceed without strict guidance and training.

The flexibility of the telecine system, with its range of available contrast, masking, programmable scratch and defect elimination, and colour balance controls, together with the use of wet gates, does enable broadcast quality restorations to be made of film that cannot easily be restored by film methods. This is particularly true of some faded colour negatives and prints and early unmasked colour negatives. Many colour prints of the 1950s and 1960s are too faded to use this method. However, it is unfortunate that many films remain in archives unrestored, even unseen, because restoration to film is too costly or not practical, when a broadcast quality tape could be made with all the general quality restored except the resolution.

There are a number of scanners suitable for archive film in use today. The higher the resolution the longer this takes. The Genesis and Cinespeed scanners from Kodak and Oxberry can scan up to 4000 pixels per line but at this resolution it takes over 20 seconds per frame. At this rate a feature film would take around 60 000 minutes or 1000 hours. Lower resolutions are faster and one of the fastest and most practical is the Spirit from Philips, which can scan 6 frames per second at 2000 pixels per line, or about one-quarter of real time. A 90 minute feature film takes 6 hours to scan, but more if correction is carried out at this stage. Many optical film printers are slower than this.

20.2.6 Changing the image

Once a film frame is scanned to produce a digital record, it is stored in a frame store, on disc or tape. At this stage the image data is in the form of a digital master, although not yet in a practical medium that can be stored conveniently.

Using a computer workstation the image data is manipulated, much as a telecine operator might correct for fading, contrast, dust images and scratches, at a range of resolutions, depending on the software employed. Several existing softwares (Cineon, Domino, Illusion, Inferno, Matador) exist for this directed at the production of special effects for television and the cinema. None was originally directed at archive film restoration, but most have aspects that are useful.

20.2.7 Re-recording back to film

Once corrected, the data is then re-recorded back onto film in one of several devices, at varying resolutions. The original scanned resolution may be used, or another software may be used to 'enhance' the resolution by doubling the number of lines recorded. The highest resolutions possible at re-recording are approximately equivalent to that of modern Eastman 35 mm film, although many archive films have considerably lower resolutions and may not need this.

Film recorders may be devices that photograph a cathode ray tube screen or use lasers with the scan driven by rotating mirrors, usually one scan is needed for each colour separation for each frame. These recorders vary is output from one frame every 30–40 seconds (e.g. the Solitaire III, conventional CRT technology) to the fastest recorder on the general market, the Arrilaser at 2–4 seconds per frame. Another recorder, the new Celco Xtreme Nitro, using a CRT, fits between the two in output (and cost).

20.2.8 Cost

Cost is critical, and at present, because the scanning rate, and especially the re-record rate, is low, no archive can justify the expense for the restoration of complete film lengths. In London, the basic price for scanning each frame of 35 mm film into framestore, and re-recording it back onto film again is £2 or more (and was £10 two years ago). However, it seems that modern film production will increasing use film simply as the camera material, carry out all the editing and other image manipulation at the digital stage and return to a film negative only if a film version is needed for theatrical release. This will have a profound effect on price over the next few years and bring digital restoration into the region that archive can justify.

The workstation time is also costly, with prices as high as £500 per operational hour, although these are falling. There is good reason to believe that these prices will continue to fall too.

Two techniques now under investigation may offer good alternative approaches. The first is the relatively untried alternative of scanning at broadcast resolution, which is fast and simple, line doubling using special software that enhances the apparent sharpness, and then transfer back to film at about the 1440 pixels per line. This is significantly less costly and quite simple. Another approach is to use a telecine with a scanning capability (such as the Philips Spirit Data Cine) to scan at high resolutions an already corrected and modified image. Many telecine grading and image control systems allow this now at broadcast resolution and the Spirit has its own limited controls at 2000 pixels per line. Experiments suggest this is well worth pursuing but needs a new grading system capable of sophisticated grading at high resolutions.

20.2.9 Film stocks for film recording

The film stock used for the final restored image is a colour negative (or a black and white negative) and the slower lower exposure recorders use camera film stocks. So far only a few recorders like the Kodak Lightning and the new Celco recorder can utilize the finer grain but slower Eastman Colour Intermediate 5244.

20.2.10 The problem of long films

At present the prices preclude the restoration of faded films where the problem is found throughout the entire length, and only short damaged sections currently justify this costly technique. However, the fact is that until now even those organizations that produce digital effects have not generated complete films or even very long lengths of film by this route. Usually the product is a 15–60 second commercial or a short section of special effect cut into normal negative. Producing an entire feature by scanning workstation manipulation, rendering to a new digital record and re-recording back to film is either rare or has not been done. Several companies are trying this now, and finding that new techniques are needed.

One production procedure that may become a routine quite soon is the use of Super 16 mm negative film for shooting, scanning this at

2000 pixels per line and re-recording back to 35 mm negative for the production of release prints. Several companies are trying this, and finding problems in consistency of image. Special negative cutting techniques are needed because the re-recording process can, as yet, only work in short lengths that have to correspond to scenes or groups of scenes. This adds to the cost, and these techniques will also be needed for restoring entire archive films.

20.2.11 Scratch removal

There is some academic resistance to the 'cleaning up', or the excessive cleaning up, of old cinema film images. Scratches are sometimes regarded as part of the 'patina' produced by time, much as it is seen on a fine piece of antique furniture. Modern photochemical film restoration and wet gate printing can remove only the scratches on the film being handled and cannot deal with 'copied' scratches. If required, a modern telecine can remove almost every scratch, and speck of dirt, on a broadcast quality transfer, using Digital Video Noise Reduction, and digital restoration can remove absolutely every scratch, even if printed in. Should we be doing so?

20.2.12 Briefing the restorer

It is clear that digital restoration, because of its effectiveness, is here to stay, and as the process becomes more productive, it is only a matter of time before the film archives' budgets, the cost of the equipment, and the price of the service, converge. We may not see the restoration of whole films in their entirety as soon as we expected, but eventually this will happen.

In the meantime, the archives and restoration technologists must consider the technical, and perhaps ethical, problems in preparation for these new technologies. The concerns are similar to those that should be felt by archivists transferring film to broadcast quality video, but are far more extensive.

Until now, restoration has been a process of using whatever modern film stock the film stock manufacturer currently supplied for modern production purposes, in order to copy an old image. As a consequence of the increased flexibility and range of final achievable results, a major effort is needed for technical film historians to understand and research what the early cinema images really looked like, in order to brief the restorer.

Lack of precision on the part of archives in specifying what is an acceptable restoration does not matter a great deal when the range of possible results is limited by the narrow choice of photochemical routes and therefore the final results. Digital restoration makes anything possible, and the restorer must be told what is needed.

The problem may be a lack of interest in the 'forensic', or technical, aspects of cinema film production, both in film manufacture and in the processing laboratory. This is in distinct contrast to the restorers' and conservationists' attitude to some of the fine arts; considerably more is known about ceramic colorants, oil based paints or medieval wall paints, than about quite recent cinema dyes.

20.2.13 Dye fading in tinted and toned films

The metallic colour Prussian Blue was used extensively as a toning colour until 1930, and as a subtractive primary colour on both two-colour and three-colour film, until 1950. Almost all old Prussian Blue images today are darker, approaching black or neutral, or a dense 'navy blue', while a few seem to have been decolorized entirely in the centre of the frame, presumably due to the irradiation from projector lamps. Yet Prussian Blue produced as an image today, using a 'recipe' from 1910, is a clear brilliant saturated cyan-blue, startling and vivid and quite unlike the images in archives. We should not be surprised at this. Unlike restoring a painting, restorations of film are carried out by producing a new image rather than restoring the original artefact, and while this might be unfortunate, it is necessary. A benefit in this approach is that it could allow the restorer to aim for a 'simulation' of the original cinema experience, rather than a copy of the tired image left today. This aspect of film restoration reveals what should be a major concern of the restoring technician – his or her brief must be precise enough to define whether the Prussian Blue should be as it is now, or as it was originally. It must be appreciated by the archivist preparing the brief that the operator at the workstation can do either, or make it a different colour altogether.

In practice, only a few photochemical restoration techniques approach this flexibility, the most notable being the double pass printing system for restoring tinted and toned images (called Desmetcolor). Once the technician realizes the colour required, for example the saturated colour of unfaded Prussian Blue, that hue can be produced, rather than a copy of the faded film colour.

20.2.14 Faded integral colour films

Relatively few photochemical restorations of faded images have restored the image to its original appearance (although sometimes the restorer believes that this is achieved), and there are images in archives which have faded so much that one or more dye is completely missing from the image.

Photochemical methods for restoration, for example using separations to correct for dye contrast, or the various masking methods, are tedious, costly and slow, and require an experienced technician. Often the results are very disappointing.

Digital restoration of faded colour films is very effective. Minor fading, typical of some negatives, can be corrected on a conventional telecine and in the case of a scanner such as the Spirit may require no further workstation time. Serious fading, where one or more dyes is completely missing or present to only a tiny extent will need a lot of time with a sophisticated software (such as Domino or Inferno) and the image may literally have to be painted in by hand.

Inevitably the operator at the workstation or the telecine has total control. Without a specification to work to an operator will make a restoration of a 1920 two-colour print and a 1935 Technicolor print both look just like modern Eastman Colour, or whatever the technician wants to see!

20.2.15 The limitations of digital restoration

Despite all the enthusiasm for digital restoration, there are limitations. The degree of restoration back to the original image is restricted, like photochemical restoration, to the range of tones and colours produced by the modern film stocks used for the final image. Consequently digital restoration of additive images like Dufay, Kodacolor and Prizma can be no better than can be achieved now since the subtractive dyes of modern films are less saturated than the additive filters of these old colour systems. Also many bright tint colours of the 1920s were more saturated than modern dyes can recreate. It seems likely that other examples will occur.

20.2.16 The future for digital restoration

At present digital restoration is not affordable by archives, and the techniques are not yet fully in place to allow the restoration of complete films, although the technique is imminent.

An interesting result of all this discussion on expensive restoration techniques is the revival of interest (probably temporary) in some of the more costly forms of conventional photochemical restoration. It seems that if archives are contemplating spending money on digital restoration with prices in sterling pounds per frame it would be worth their while revisiting some of the complex masking techniques occasionally used for making restored colour prints from faded images. The old Flashed Dupe Mask method recommended by Kodak years ago is being reconsidered, and recently several other similar masking methods have appeared in technical journals. However, in the opinion of most technologists who have seen the results of digital restoration, these methods may be cheaper, but they are not as flexible, as repeatable or as good.

In November 1997 Eastman Kodak estimated the future potential of digital restoration in a technical paper at the SMPTE conference in New York. Eastman compared the cost today of a photochemically restored colour print (of, for example, an old Technicolor or Cinecolor 100 minute feature film) at $75,000 by methods, to $1.5 m restored digitally.

Eastman Kodak believes that in future the cost of digital restoration will increase where it is still done by hand (manually), but that automatic scratch and mark removal software, if used for the whole film, will reduce the cost to about $75,000 by about 2003. However, since most films will require a mixture of automatic and tedious and costly hand retouching, this will still cost around $0.5 m by 2003.

There are, however, the other options like line doubling, and it seems that Eastman may not have take into account the involvement of scanners such as the Spirit. Very little experimentation has been done to see if the results of re-recording from these images and using line doubling are acceptable to archives. At the time of writing this forecast seems to be unduly pessimistic – and within months these prices will be down to affordable levels.

However, once the price comes down the archivist will have to be prepared for the question the technician may ask – What do you want? To answer this archivists need technical information about the original image, much of which is not generally available yet. A small start was made by the Cinemateca Espagnol in organizing a workshop for FIAF in April 1999 in order to create a new database of technical film stock data. This will be needed in the future as a basis for defining the standards for restoration, and is essential before all this information is finally lost for ever.

Stop Press – February 2000

As this book is going to the publisher, several new factors have entered the arena, which will undoubtedly have an effect on the future of digital restoration:

1. It seems that there may be no need to carry out all the restoration processes at the workstation, which is time-consuming and costly. Correction of faded film even severely faded can be carried out at the scanning stage on the latest range of high resolution scanner/telecine units such as the Philips Spirit Datacine, and tests have already shown this to be very successful. This opens up the possibility of other corrections being carried out prior to data recording.

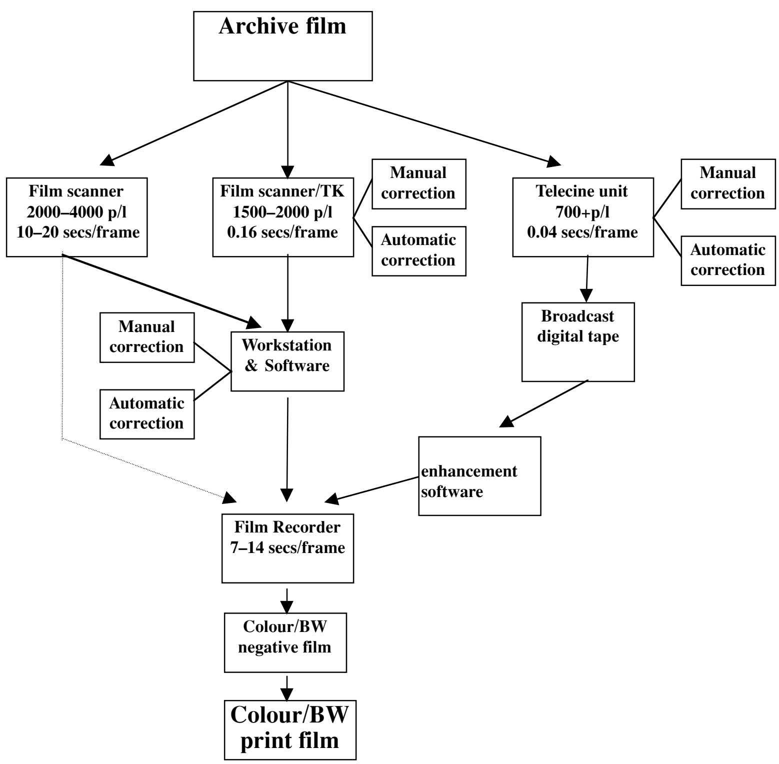


Figure 20.1 A range of possible routes for the digital restoration of archive film

2. In the USA, high definition television has spawned several different high resolution compressed video formats. These can be generated from film at real time, 24 frames a second (the fastest data scanner is the Spirit scanning at 2000 pixels per line which operates at 6 frames per second). These compressed formats seem to be quite adequate for a whole range of archive film.
3. In Europe, the concept of Digital Film (called in the USA 'Digital Intermediate') is gaining advocates. By 2000 some ten or twelve feature films from high budget US majors to low budget features shot on Super 16 and released on 35 mm have used the technique of shooting on film, transferring to a digital high resolution format for all conforming, effects and all post-production and being recorded back to film (a single uncut length) for printing. Many in the modern industry believe this will firstly eliminate the traditional intermediate films, such as black and white 'Fine Grain' and Eastman Intermediate and Internegative, and replace them with special digital film formats. The effect on the archives will be dramatic, since the archives rely on the traditional films for their preservation and restoration. This will certainly force a change to digital methods.
4. The general trend from cinema film projection to video projection is clearly accelerating and the quality of projection has increased in the last year. The next Star Wars is destined for a video projection in the cinema. This therefore further accelerates the day when many film stocks currently used for preservation and restoration will no longer be available. Once this occurs, digital preservation will be essential as only digital methods will exist.

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Part 4

TECHNIQUES AND CASE STUDIES

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21

Menschen am Sonntag – a reconstruction and documentation case study[1]

Only when it is possible to examine and discuss the work that an archive, a restorer or a laboratory has carried out on a film can it be said that the restoration is complete. Anyone involved in the field has had reason to get upset over the indiscriminate use of the word restoration over the past few years. We do not know what the word means anymore, now that it is applied to anything anybody does with 'old' films, whether it might simply be printing them up from existing material, or complex projects involving half a dozen sources and years of zealous work. If we who do this kind of work would document what we do in a way that is readable and accessible by anyone interested, our efforts could be controlled and discussed in a much more fruitful way. Also, we would make it much easier to re-address certain problems of a film that had to be left unresolved once better material turns up or new methods of restoration promise better results. Keep in mind that already many films have to be 're-restored' from secondary sources, because the underlying original has decomposed or was wilfully destroyed. If we could save ourselves the ordeal of finding out just exactly what someone did to a classic film 20 years ago, and why he or she did it, life would be a lot easier!

Anyone restoring a film should at least have the discipline to lay down on paper some principal information, in order to secure the future life of the film and its restoration:

1. What are the sources that can be used for the restoration?
2. What is the aim of the restoration (which version of the film is going to be restored)?
3. What is done to the film to achieve what?[2]

Let's take as an example the new version (to avoid just for once the word restoration) of *Menschen am Sonntag*, which was prepared by the author in the Nederlands Filmmuseum in Amsterdam in 1997, and printed at L'Immagine Ritrovata in Bologna. Even though it is impossible, for reasons of space, to explain in this chapter every intervention made in the course of the restoration, the information provided here may still indicate the direction which the work has taken. At the same time, a record system will be put forward which offers a simple method for documenting surviving material and the restoration decisions taken, as well as aiding better communication between the archives and the laboratories involved in the project.

21.1 ONCE UPON A TIME THERE WAS A FILM

In the summer of 1929 a group of young film enthusiasts shot a film on the streets of Berlin and at Großes Fenster on the banks of the Wannsee. The script was improvised according to what had been filmed and was largely the result of an ongoing debate between the participants at a coffee table. It is a simple story about a summer day in the sun, in the countryside, interspersed with documentary footage of the city. The working title of the film was programmatic: 'So ist es und nicht anders!' (That's just the way things are!) – life has to be captured on film. The actors were amateurs, and most of them played not a role, but themselves. The spokesmen for these young people and soon director-to-be, Robert Siodmak, had no film experience except for a couple of jobs as assistant editor and writer of intertitles for foreign films. In the winter of 1929/30 the film was completed and presented to the Berlin censor who on 29 January 1930 allowed its circulation without cuts. At this point the film was 2011 metres long and divided into six reels.

After an initial rejection by the cinemas of Berlin, the first projections in February 1930 were well received by critics and the public alike. The unexpected success signalled the beginning of Robert Siodmak's career as a director and the professional recognition of the cameraman, Eugen Schüfftan who, until then had been known only by a small circle of specialists as a special effects technician. Other members of the group (Edgar Ulmer, Fred Zinnemann, Kurt Siodmak, Billie Wilder) were soon beginning successful careers in the world of cinema, which were to continue even after their emigration in 1933. Only the actors were to remain in Germany where they disappeared again into the crowd from which they had emerged.

After the Second World War, when archives and film enthusiasts began to write film history as a history of film art, Siodmak's film was enthusiastically rediscovered and became a classic. The use of amateurs and of real sets caused it to be interpreted as a precursor of neo-realism. There was also a fascination about its leisurely view, apparently free from commercial interest, of Berlin life in the 1920s, of a city culture which would only a few years later be suffocated by National Socialism. Another reason for the cult status of the film with the cinephiles was the belief that *Menschen am Sonntag* grew out of opposition to the film industry. Thus it seemed to anticipate the 'politique des auteurs', a central thought among the leading figures in archives and film circles at the time. Prints of the film began to circulate among the archives and were shown in the specialist cinemas around the globe.

The version which was and is shown was certainly not the original, but the duplication of a copy with Dutch titles from the Amsterdam distribution company Filmliga, which survived the war in the collection of the Uitkijk cinema in Amsterdam, and had then been passed on to the Nederlands Filmmuseum. At the same time, copies of a very similar version with intertitles in French and Flemish stemming from the Cinémathèque Royale in Brussels were also exchanged with other archives. Both the Amsterdam and the Brussels versions were subject to further duplication and further exchange, and thus the film went around the world. Neither the original negative nor complete prints of the original version distributed in Berlin in 1930 – around 400 metres longer than the Dutch version – has ever turned up again to date.

In the Nederlands Filmmuseum a restoration programme of the Uitkijk Collection is currently in course. Thus all surviving originals and the previously produced preservation elements of *Menschen am Sonntag* were examined again, in order to determine whether a new restoration would be advisable.

21.2 WHAT CAN STILL BE FOUND

We do not intend to make reference to all of the copies that exist but only to the 'originals', or in other words to those copies which date back to the period of the production, and original distribution of the film and which represent the starting point from which, so far as we know, all of the existing versions derive. Also, a comparison is made with the version prepared by Enno Patalas for the Filmmuseum in Munich.

21.2.1 The Uitkijk copy at the Nederlands Filmmuseum, Amsterdam

Agfa stock, nitrate, 1615 m, Dutch intertitles (spliced), black and white
Origin: Filmliga, Amsterdam

The copy is conserved in a rather good state, even though there are scratches and it is generally much shorter than the original version. Damage is noticeable in particular at the reel-ends, where the closing shots have been rather thoughtlessly marked and scratched, or have been lost altogether. The film has been put onto large and small reels many times in its lifetime, thus by now there are more old and new reel-ends and related damage to be found than one would normally expect; at present the film is spliced onto three large reels. Mainly because of this damage, the copy is now shorter than when presented by Filmliga to the Dutch censor in 1930, then 1685 m long. (The film was given a projection certificate on 17 November 1930 after 24 m had been cut. A shot with a naked tailor's dummy in a window and the scene which shows Wolf on the beach with his arm around two girls were cut.) At this point the film consequently should have been 1661 m long. On 31 December 1931 the censor stepped in again, after which the film measured 1640 m. Which shots were cut at the second intervention is not indicated in the censorship papers. In the copy conserved, the naked dummy is missing, as a result of the censorship order, but the scene with Wolf and the girls, which was also forbidden, remains, though not in its entire length.[3] The text of the intertitles sometimes departs considerably from the German text documented on the Berlin censorship card issued 29 January 1930.[4] Surprisingly, there are also intertitles on the film which the Filmliga, in a list dated 8 November 1930, had indicated as '*verfallen*' (to be dropped) for what reason ever. Generally, there are many more titles present than in the original German version.

21.2.2 The Uitkijk copy at the Fondazione Cineteca Italiana, Milan

Agfa stock, nitrate, 1479 m, Dutch intertitles (spliced), black and white
Origin: NFM (Filmliga, Amsterdam)

This copy arrived in Milan, from NFM, in 1953. One supposes that this copy was considered to be surplus in Amsterdam, probably because it was incomplete (or perhaps it subsequently became so through use and further damage?). It comes from the same negative as the copy in the Nederlands Filmmuseum, and was probably made in the same printing. The photographic quality is therefore very similar, though with slight differences in contrast (perhaps the result of uneven developing in the laboratory that made these prints) which are generally (though not always) to the disadvantage of this copy. The copy is more scratched than the one kept in Amsterdam. In addition, the emulsion is beginning to deteriorate in several places. The damage around old and new reel-ends is considerable, but fortunately this often affects different shots than in the Amsterdam copy. Because of that, it has been possible to restore several scenes lost or damaged in the Amsterdam copy by combining them with parts of the same shot from the Milan copy or replacing them altogether.

Strangely, the intertitles in both of the Dutch copies contain mistakes regarding the female roles, but of different sorts. In the Amsterdam copy, the actress Christl is a shop assistant, while in the Milan version she is a model and Annie (the true model) is described as a shop assistant.

21.2.3 Duplicate negative at the Danske Filminstitutet, Copenhagen

1948 Harrow Kodak stock, nitrate, 1575 m, Dutch intertitles (mostly flash titles), black and white
Origin: duplicated from NFM copy (Filmliga, Amsterdam)

This negative was produced in 1949 from the NFM Uitkijk copy before it had been further used and damaged. The duplicate keeps the old division into six reels. There are also leaders with Dutch titles and print-through written in German. The Dutch intertitles have been, almost without exception, reduced to the length of two-frame flash titles (a strange practice by the early Danish archivists which is commonly encountered and has cost subsequent generations dearly). The hope of restoring certain scenes which had been damaged or lost in the Dutch copy by using this negative was premature. After several tests, the photographic quality was found to be too poor. It is thought that certain archives have, however, obtained prints from this negative, which would explain the poor quality of some of the copies in circulation. Despite this, the negative has been useful as a point of comparison, making it possible to establish the original length of certain damaged scenes, and to establish the position of the original six reel-ends.

21.2.4 Gexefilm copy at the Cinématèque Royale, Brussels

Zeiss-Ikon stock, nitrate, French/Flemish intertitles (spliced) on 1931 Harrow Kodak, Gexefilm-title-leader on 1932 Canada Kodak, reel 6 on Gevaert acetate, 1681 m, black and white
Origin: Gexefilm, Brussels (via Filmliga Amsterdam?)/duplication from NFM copy (reel 6)
Particulars: the second half of the fifth reel is also printed on Zeiss-Ikon stock, but has a light orange tint. The entire sixth reel is a duplicate of the NFM Uitkijk copy.

This is a copy from Belgian distribution (Gexe-Film) which must have arrived at the archive incomplete, and was then completed a considerable time ago with material from other sources. The length indicates that after this operation the copy matches reasonably well the version presented by Filmliga to the Dutch censor in November 1930. The difference in length, in comparison with the NFM copy, is due above all to the intertitles, which are generally longer in this copy. (Strangely, the text of these French/Flemish intertitles is very different to the Dutch intertitles. The error about Christl playing a shop assistant is also made here, where she has in fact become a shoe seller). Otherwise, this version has been cut in exactly the same passages as the Uitkijk copies, in comparison to the German original. However, the shots which the Dutch censor cut (in the Dutch positives), remain in this copy. There are some extra shots in the first reel in the sequence establishing Wolf and Christl, which are absent in both Uitkijk copies. One can see that the Belgian copy was made from the same negative as the Dutch copies, but perhaps in a different laboratory, and obviously later, because some of the titles are on 1932 film stock. From the photographic point of view it is printed with much less contrast, and therefore looks generally weaker and less brilliant. Part of the fifth reel has been substituted by a copy on Zeiss-Ikon nitrate which has a slightly orange tint. The entire sixth reel has been reprinted from the NFM copy and was therefore ruled out for further duplication. Despite these limitations, this copy contains certain scenes which are missing elsewhere and its low contrast has proved to be more appropriate for the duplication of certain problematic sequences than the more brilliant and contrasty Dutch print.

21.2.5 The Cinématèque Suisse copy at Lausanne

Agfa and Berlin 1929 Kodak stock, nitrate, 1158 m, German intertitles (spliced), black and white
Origin: unknown

This copy (in the Swiss archive since 1942) is the only known surviving element of the German version of 1929/30. Unfortunately, it is heavily damaged and no longer complete – the first and second reels are completely missing. Many scenes are missing in other parts or they are found to be abridged by damage. However, there are entire passages conserved here, above all of a documentary nature, which are absent in the other copies. It is therefore thought that these scenes might have been cut by Filmliga when preparing the Dutch version. (The reason being presumably the desire to concentrate more on the narrative plot which involves the four central figures.) The copy is almost entirely edited in positive and even some of the dissolves are spliced and not printed, which seems unusual for a film from this period. On the other hand, the final passage of the film is not edited in positive and, despite this, is shorter than the Dutch version. Those intertitles which are present correspond with the German censorship card from 1930. From the photographic point of view this copy is poorer than the Uitkijk copies for most of its length, generally being on the lighter side. This copy has also been printed from the same negative as the Dutch and Belgian versions – and presumably before them. We can therefore conclude that all existing nitrate prints were taken from the same original negative, which has undergone several interventions between the making of the different versions we have found.

21.2.6 The Munich restoration (print from Stiftung Deutsche Kinemathek)

Kodak 1995, acetate, 1742 m, German intertitles (printed), black and white
Origin: Munich Filmmuseum (Cinémathèque Royale/Cinémathèque Suisse), reprinted from

the Munich cutting copy by L'Immagine Ritrovata, Bologna

This is a copy of the so-called Patalas version which was much talked about in the 1980s. Enno Patalas, during his time as director of the Munich Filmmuseum, had edited German instead of French–Flemish intertitles into a copy produced from a duplicate negative printed from the nitrate copy in Brussels. He took the text from the German censor's papers and imitated the typography of the intertitles of the Lausanne copy. Around 100 m of additional footage duplicated from the Lausanne copy were edited into reels 3 and 4.

When Chris Horak took over from Patalas in 1993, he assumed the task of making safe the famous Munich restorations of German classics. Most of them, including *Menschen am Sonntag*, existed only in the form of cutting copies. In this case, preservation took place by simply making a duplication of the edited copy. This is the reason why this version is rather disappointing in quality, although it is a good duplication of what there was to duplicate. However it is at least three generations away from what could have been obtained from producing a new negative based on the originals still in existence. In the sixth reel we are even further away from the original since the Brussels copy contains footage which had already been duplicated. Another fundamental defect of this version is that not all of the scenes missing from the Brussels copy but conserved in the Lausanne and Amsterdam copies have been added. Also, several intertitles have been inserted in the wrong place, others show spelling errors, and all of them are too small and in the wrong typeface due to the imperfect work of the graphic designer who was given the job of imitating the Lausanne copy.

Having said all this, it is important however to point out that this version has given valuable indications as to what was lacking in the versions of *Menschen am Sonntag* that were previously available. For the editing of the new version, this copy could also serve as a guide as to where additional material had to be inserted. As so often happens, the pioneering work of the Munich Filmmuseum done in the 1970s and 1980s has shown the road to be followed in order to reconstruct a better version. It is easy to mock these versions nowadays, but one should not forget that we are in an immeasurably better position today, with the archives being much more open, and the rediscovery of many elements which were hitherto unknown.

21.3 THE RESTORATION

It was decided not to reconstruct the shortened Filmliga version, which had already been preserved by a duplicate negative and prints made by the NFM some years ago. It was our intention to try, so far as possible, to reconstruct the original German version, combining duplicates of all of the copies available in order to create the most complete version possible. The fundamental principle had to be to document all original material conserved, without changing anything except for necessary repairs of perforations and similar operations. A scene schedule was drawn up with the editing sequence, length of each take, key words to summarize the contents and (where needed) notes on the damage to each different version. The comparison between the six versions, thus set out in spreadsheet form (see Figure 21.1), provided the basis for subsequent work which was aimed at producing a version containing the best picture quality possible and a certain completeness as well as correcting previous sequence errors.

The NFM copy was chosen as the basis for the reconstruction, both for its photographic and mechanical quality, and was completely reprinted. Inserts were taken from the other copies to replace damaged or missing scenes. The choice of position for footage which was completely missing in the Dutch version was normally dictated by the context of the scenes in question, and largely suggested by the Munich version. We include various examples below.

The major changes in comparison with the Filmliga version occurred with the additions made possible from the Lausanne copy. The longer documentary passages (reel 4, nos. 473–522, no. 535 and nos. 542–577), which were missing in the Dutch and Belgian versions, were mostly inserted in the same position as they appeared in the Munich museum version. The scenes that were still missing in the Munich restoration, such as the long sequence of Sunday afternoon in Berlin (reel 4, nos. 413–457), and also part of the sequence showing Berlin on the move (reel 3, nos. 262–274, nos. 279–281) were inserted in the position in which they were found in the Lausanne copy. In reel 1, the scene sequence has been changed in such a way that the characters enter on scene in the order set out in the censor's papers – first Brigitte, then Wolf (reel 1, nos. 13–19). In the film finale the scene sequence, clearly altered by Filmliga, was rearranged according to the sequence in the Lausanne copy (reel 6, nos. 845–851), which, in this sequence as well, contained two shots which had hitherto not been included (reel 6, nos. 837–838). Five shots in this sequence were removed (reel 6 between no. 842 and nos. 843) because they clearly came from cuts in reel 1 of the Dutch version which Filmliga had re-edited into the end of the film. These shots could not be edited back into reel 1 and therefore remain out of the film until such time as it is possible to examine an original copy of the German original version of the first two reels and to discover at what point they are to appear – which is to say perhaps until forever.

Many shots which had been damaged in the NFM copy were taken from the Belgian copy, as well as a whole series of scenes which were missing from reel 1 (nos. 30–39, nos. 43, and 45–46) and longer beach scenes in reels 3 and 4 (nos. 323–336, nos. 366–386, nos. 389–412) which were difficult to satisfactorily duplicate from the NFM copy.

The copy which was least used was that of the Cineteca Italiana, mainly because it is almost entirely identical to the NFM copy, but shorter and in a worse state of conservation. But even this copy proved useful for the substitution of sequences which had been damaged in the old or new reel-ends.

Let us take the end of reel 2 as an example. In the Munich museum version, we see Erwin leaving one Sunday morning after writing a message to his girlfriend, Anna, who is sleeping (no. 254). Erwin moves towards the door and then returns, for no apparent reason, to the table where he had been sitting earlier. The Brussels copy of this scene, on which the Munich version is based, bore large blue and red reel-end cue signals, drawn on in wax several decades ago. These marks had not been removed before the film was reprinted in Brussels and they therefore appear rather prominently as irritating black blots before the scene breaks off in the Brussels and Munich copies. In the Dutch version, however, two more scenes follow in which we see an Erwin who is rather more sociable compared to his normal coarseness. No. 255 is a look back at Anna who is sleeping, with the table containing the message and the remains of the previous night's card game in the foreground. Then Erwin crosses the picture, passing towards the gesture of tenderness which follows in no. 256, in which we see Erwin counting out several cigarettes and leaving them on the table for Anna before finally leaving the apartment, the following fade-out signals the end of reel 2. No. 255 and no. 256 are conserved only in the NFM and Cineteca Italiana copies (as well, of course, as in the Copenhagen version which is, however, unusable). No. 256 is damaged in both copies by a mass of lines and scratches so as to make it necessary to use both copies in order to reduce the damage marks to the minimum possible. This has proved useful for all of the old reel-ends in order to improve as far as possible the scenes which have been damaged at these points.

The technical part of the restoration was entrusted to our colleagues at L'Immagine Ritrovata. The duplicate negative was printed wet gate on an intermittent optical printer and, apart from normal grading for every shot a graded flashing was used in order to tone down the sometimes extreme contrast found in the original prints. The negative was then underdeveloped in order to reach a gamma of 0.5. The new positives were printed without further modifications on a continuous printer, then also underdeveloped to reach a gamma of 2. As a result many images which had until then been seen simply and erroneously as expressionist black and white, have regained depth, thanks to the grey tones which have been recovered by the underdeveloping. The faces once again show reasonable skin tones and the heavy graininess of the film has been somewhat reduced.

The German intertitles (which are quite different in text and contents to the Filmliga version) were rewritten according to the original censorship card and redesigned using the

Lausanne copy as a model. For this purpose frames from this copy were read by a scanner and electronically cleaned, then re-filmed. The intertitles for the first and second reels, which were missing in the Lausanne copy, were handwritten *de novo*, again using the censorship card as a guide for the text, and the Lausanne intertitles for the style.

Finally, the main differences between the Munich version and this new version made by the NFM are: first of all the addition of the scenes which were still missing as well as the improvement of the form of the intertitles (and their arrangement within the film). Secondly, a significant improvement in the photographic quality which was achieved above all by the careful duplication of the original material.

21.4 WHAT HAS NOT BEEN RESTORED

Even this new version, which is 1839 m long, would have notable gaps in comparison to an original well-conserved copy, which, however does not exist. Thus, for the moment, these gaps will have to remain. In particular they relate to missing scenes from the first and second reels which amount to a total loss of approximately 170 m. Filmliga cut 400 m, of which around 230 m have been rediscovered in the Lausanne copy. But we do not know precisely what has been cut from the first two reels of the film, because they are missing in Lausanne. With the exception of the five shots mentioned above showing city traffic (cut between nos. 842 and 843), which Filmliga inserted into the reel 6, we have been unable to find out anything about the missing shots from reels 1 and 2. We can see from the German censor's papers that large cuts were also made in the sequence which takes place on Saturday afternoon at the house of Erwin. The papers refer to intertitles which could not be fitted in the surviving scenes and lack of continuity between shots lead us to suppose that something is missing here.

Despite the enormous care spent, a great deal of physical damage to the film stock was impossible to correct by traditional methods. We refer in particular to signs of careless handling (holes, scratched cue dots) which successive generations of projectionists have left on the film. However, it was decided (contrary to usual practice) not to cut the damaged frames. By doing so, they would have been lost for ever. Instead, we have transferred every single recoverable frame of damaged film onto safety film using conventional printing methods. Thus in a few years time, when digital technology will be financially within the reach of archival projects, it will be possible to remove these defects quite easily.

Serious shortcomings in the original material were also impossible to resolve using traditional technology. Already the original negative is responsible for some of the imperfect quality of the images, which were filmed, in this *no budget* production, using a 1915 Eclair. This ancient camera was placed on a tripod which had no gyroscopic head and every movement therefore produces a rather wobbly effect. Even the movement of the cranking of Eugen Schüfftan is quite noticeable in some shots, which had to be made while the tripod was loose. The heavy graininess of the original negative (as far as one can guess from the original prints) might be caused by the fact that its developing was often manipulated. Schüfftan had only normal light (and a few extremely poor reflectors) for the shooting of exteriors and was therefore obliged to adopt unsatisfactory compromises during exposure and developing in order to obtain, from the relatively insensitive film stock at his disposal, acceptable images of scenes shot in the shade. We must not forget, however, that a certain non-professional look was part of the idea of the film ('That's just the way things are!'). It is therefore necessary to use other parameters to assess the photographic quality of this film in comparison to an industrial product of the same period, even when a restoration with digital support might be possible in the future. Otherwise one would run the risk of carrying out a hyper-restoration, which might sterilize and flatten the rough finish which represents one of the fascinations of this film.

21.5 DOCUMENTATION

During the restoration of *Menschen am Sonntag*, an attempt was made to document the work in the best possible way in order to make the decisions which were taken more comprehensible. The idea was also to leave open a path leading back to the original material in case of improved printing methods becoming available in the future, or mistakes being discovered, or to facilitate the addition of new material when it may turn up at a later time. In order to document the state of the material at the outset a detailed record of the film was compiled which would enable a comparison between the surviving copies. The record also makes it possible to check the restored version, and to find out, for each and every shot, from which of the original copies it was taken, with specific details about each source chosen for the restored copy. Further, it is possible to examine the differences in the sequence of shots that has been found in the originals, and to compare it with the sequence that has been chosen for the restored version.

A fundamental problem in the record is immediately apparent if one examines the description used to define the individual takes. These descriptions can never reflect the richness of the images in such a way as to be always recognizable when removed from context. We therefore do not have a truly usable scene description in this respect. But on the other hand, for a record of this kind, it is not essential to have a precise description as much an easy means of identifying a take in its context. It is therefore sufficient to have some minimal indications which would be quite inadequate for other purposes. If the record were to require a point by point description of the film in relation to action and form, then it would be necessary to modify our descriptive method.[5]

The inevitable need for innumerable corrections in the documentation in the process of rolling through the film again and again normally leads to rather lengthy sheets of paper which are not handy on the editing table. After some layers of scribbled corrections have been added they tend to become illegible to outside collaborators. This caused us to reflect upon the possibility of using a computerized schedule. With the help of Nicola Mazzanti I developed a draft which

MENSCHEN AM SONNTAG

Protokoll der Materiallage und Auswahl restaurierte Fassung, erstellt von Martin Koerber 1997/98

Wortlaut der neuen Zwischentitel nach Zensurkarte B 24926, Schrift nach Kopie Lausanne. Titel sind im Protokoll *kursiv* dargestellt

			Restaurierung NFM		FCI, Milano			NFM Nitro		
No	FCC	Quelle		Frames		Frames	Anmerk.		Frames	Anmerk.
1	0	neu	*Filmstudio 1929 zeigt seinen ersten Versuch*	98	*Div. Titel aehnlich NFM*			*Holl. Titel*		
2		neu	*Menschen am Sonntag. Ein Film ohne Schauspieler*	120	*einige fehlen jedoch*					
3		neu	*Leitung/Manuskipt/Kamera*	244						
4		neu	*Regie: Robert Siodmak , Edgar G. Ulmer*	104						
5		neu	*Diese fuenf Leute...*	253	*insgesamt*	881		*insgesamt*	1305	
6		NFM	Aufblende Taxi, blendet in	123	dto			dto		
7		NFM	Totale Taxi, Passagier	108	dto, 6 und 7 insgesamt	250		dto 6 und 7 insgesamt	243	
8		neu	*Erwin Splettstoesser...*	97	*De taxichauffeur*	82		*De taxichauffeur*	38	
9		NFM	Erwin gross, Taxameter	66	dto	65		dto	66	
10		NFM	Passagier steigt ein, wie 7	39	dto	39		dto	39	
11		NFM	Erwin gross, blendet in	79	dto			dto		
12		NFM	Totale Abfahrt Taxi, Abblende	123	dto, 11 und 12 insgesamt	200		dto, 11 und 12 insgesamt	200	
13		neu	*Brigitte Borchert...*	200	*De wijnreiziger*	98	Nr. 16	*De wijnreiziger*	69	Nr. 16
14		CR	Totale Electrola	77	Aufblende Weinhandlung	136	Nr. 17	Aufblende Weinhandlung	134	Nr 17.
15		NFM	Brigitte durch Fenster	60	Wolf gross	77	Nr. 18	Wolf gross	77	Nr. 18
16		neu	*Wolfgang von Walterhausen...*	180	Weinhandlung, wie 17	90	Nr. 19	Weinhandlung, wie 17	90	Nr. 19
17		NFM	Aufblende Weinhandlung	134	*Heit meisje uit een gramofonwinkel*	128	Nr. 13	*Het meisje...*	89	Nr. 13
18		NFM	Wolf gross	78	Totale Elektrola fehlt	0	Nr. 14	Totale Elektrola fehlt	0	Nr. 14
19		NFM	Weinhandlung, wie 17	90	Brigitte durch Fenster	60	Nr. 15	Brigitte durch Fenster	60	Nr. 15
20		neu	*Christl Ehlers laueft sich...*	116	*De winkeljuffrouw - Christl Ehlers*	152		*De mannequin - Christl Ehlers* (falsch)	133	
21		NFM	Christl gross, vor Schildern	104	dto	104		dto	105	
22		NFM	Totale Christl, Abblende	124	dto	124		dto	124	
23		neu	*Annie Schreyer, ein Mannekin*	100	*De mannequin, Annie Schreyer*	83		*De winkeljuffrouw, Annie Schreyer*	78	
24		NFM	Annie auf Bett, Abblende	114	dto	105		dto	115	
25		neu	*Berlin*	60	fehlt	0		fehlt	0	
26		neu	*Ein Sonnabend*	60	*Zaterdagavond*	74		*Zaterdagavond*	43	
27		NFM	Aufblende Schwenk Verkehr	179	dto	179		dto	179	
28		NFM	Fahrt Strasse mit Passanten	**88**	dto	**87**		dto	**87**	

Figure 21.1 Part of an Excel spreadsheet showing a comparison of different versions of *Menschen am Sonntag* (for details, see text). Key: NFM, Nederlands Filmmuseum, Amsterdam; FCI, Fondazione Cineteca Italiana, Milan; CR, Cinémathèque Royale, Brussels; DFI, Det Danske Filminstitutet, Copenghagen; SDK, Siftung Deutsche Kinemathek

could be put into action using a Microsoft Excel program, but in theory is easily applicable to any computer program containing tables, and capable of being modified according to the requirements of the situation. An advantage of a computerized record is the possibility of correcting it (and to undo corrections) with greater ease. Data can also then be easily exchanged (by computer disc or e-mail) between those working on the project (other archives, print laboratories etc.). In order to compare the various copies it would naturally be ideal to collect all the material together in a single place and examine them at the same time, for example on a dual editing table or synchronization bench. This is often not possible (because no such table is at hand, or because certain elements cannot travel) and the basic work of comparison the surviving elements of a film cannot carried out simultaneously. But if the data regarding one or more copies has already been recorded, it is then possible to read it from, for example, a portable computer on the editing table (in whatever archive, or whatever country or at whatever hour) so that an accurate comparison can be made with the material already examined. It would also be possible for different people in different archives to use data relating to copies of films and compare them by computer link. If this method of working were to become usual and standard formulae could been found to describe restoration work, this would enormously simplify and speed up projects involving more than one archive.

The possibilities for automation offered by Excel simplify the task of writing, especially when repetitive data have to be put in. Data that is repeated can be easily copied. Calculation procedures (shot length, cumulative frame count etc.) and subdivisions (into editing order or by scene number) can be carried out automatically, even making it possible to sort out material that is completely in disorder and have it immediately placed in order by the computer.

This type of record would also meet many of the demands made by Canosa, Farinelli and Mazzanti for adequate documentation:

CR, Bruxelles			**CSL, Lausanne**			**DFI, Kopenhagen**			**SDK, Muenchen**			Rolle 1		
	Frames	**Anmerk.**		**Frames**	**Anmerk**		**Frames**	**Anmerk.**		**Frames**	**Anmerk.**	**R**	**G**	**B**
Holl/franz. Titel			1. Rolle fehlt			*holl. Titel*			*Dt. Titel nach Zensurkarte*					
Wortlaut abweichend						*nur Springtitel*								
von NFM														
insgesamt	1787					*insgesamt*	3		*insgesamt*					
dto						dto			dto -Laenge Nr.6 - 254 wie CR					
dto 6 und 7 insgesamt	221					dto 6 und 7 insgesamt	249		dto- daher nicht notiert					
Un chauffeur de taxi	95					*Springtitel, wie NFM*	2		dto					
dto	67					dto	66		dto					
dto	41					dto	39		dto					
dto						dto			dto					
dto, 11 und 12 insgesamt	202					dto, 11 und 12 insgesamt	202		dto					
Een vertegenwoordiger...	114	Nr. 16				Springtitel, wie NFM	2	Nr. 16	*Wolfgang von Waltershausen...*		Nr. 16			
Aufblende Weinhandlung	139	Nr. 17				Aufblende Weinhandlung	134	Nr. 17	Aufblende Weinhandlung		Nr. 17			
Wolf gross	77	Nr. 18				fehlt			Wolf gross		Nr. 18			
Weinhandlung, wie 17	91	Nr. 19				Weinhandlung, wie 17	28	Nr. 19	Weinhandlung, wie 17		Nr. 19			
Une vendeuse de disques	109	Nr. 13				*Springtitel, wie NFM*	2	Nr. 13	*Brigitte Borchert...*		Nr. 13			
Totale Elektrola	76	Nr. 14				Totale Elektrola fehlt	0	Nr. 14	Totale Elektrola		Nr. 14			
Brigitte durch Fenster	63	Nr. 15				Brigitte durch Fenster	61	Nr. 15	Brigitte durch Fenster		Nr. 15			
Une figurante de cinema	122					*Springtitel de mannequin*	2		*Christl Ehlers laeuft sich...*					
dto	106					dto	104		dto					
dto	126					dto	124		dto					
Une vendeuse de chaussures	106					*Springtitel De winkeljuffrouw*	2		*Annie Schreyer...*					
dto	115					dto	115		dto					
fehlt	0					fehlt	0		*Berlin*					
Samedi soir....	164					*Springtitel wie NFM*	2		*Ein Sonnabend*					
dto	180					dto	179		dto					
dto	**88**					dto	**87**		dto					

1. **Preliminary account:** Precise record of existing material (compiled simultaneously or step by step at different times in different places).
2. **Programme of intervention:** The choice of the material to be used is made according to the information in the record – length of material, damage, photographic quality often leave little room for choice so far as printing is concerned (the more elaborate reasoning for these decisions should, however, be put down in a separate text such as this one, in order not to make the spreadsheet explode into an unusable format).
3. **Progress journal of work:** The record continually grows as work progresses and is supplemented all the time with further information. Experiments can carried out by simulation in the computer to find possible solutions to specific problems (for example, for the editing order). If necessary, the different work phases can be documented by saving various versions of the record, for example saving it after each working day.
4. **Final report:** Finally, the definitive record – the one that has all the information that could be obtained from the material at the end of the restoration process – becomes part of a restoration report in which the decisions taken are immediately comparable with the material that was the basis of the work.

21.6 ILLUSTRATIONS AND EXPLANATIONS

21.6.1 Excel sheet: first page *Menschen am Sonntag* record

Figure 21.1 reproduces the Excel spreadsheet. The individual copies are listed vertically, from left to right: **1**, the restored copy in the Nederlands Filmmuseum; **2**, the Uitkijk copy in the Cineteca Italiana; **3**, the Uitkijk copy in the NFM; **4**, the Gexe copy in the Cinémateque Royale; **5**, the copy in the Cinémateque Suisse; **6**, the duplicate negative in the Danske Filminstitutet; **7**, the Stiftung Deutsche Kinemathek copy (Munich version). In the **Nr.** column appear the progressive numbers of the shots, corresponding with the restored copy. If any copies differ from this order, this is indicated in the spaces relating to the these copies, as for example, in the case of scene nos. 13–19.

The **FCC** column gives the option of automatically providing a frame count of the number of frames in the individual copies (or individual film segments such as reels, or sections to be copied). For this purpose this column has to be linked with a formula to the **frames** column of the copy that has to be measured. These frame counts can then be used by print laboratories to set up the work on the machines, thereby eliminating duplication of the work of surveying and data registration for each individual copy.

Under **Quelle** is information about the original material used for the respective scenes in the restored version.

The wide columns under the names of the various archives give information about the content of the scenes, and thus also about the sequence of shots in the various prints. Intertitles are counted as shots, and are written in italics in order to distinguish them more easily (it is not necessary to fill in the complete text of the intertitle, which can be set out in a separate list). If the content of the shots in the various copies is identical to that in the restored copy (which is described first), it is not repeated but indicated with the abbreviation ‘dto’. A separate frame count (**frames**) is given for every copy which enables any difference in length to be immediately noted. A further column leaves space for notes (**Anmerkungen**) of whatever kind, for example on any deterioration or other details about individual scenes (it is possible to note more than is visible and it is possible to call up the entire text of the notes by clicking on the individual cells).

Other columns can easily be added if necessary (for example, to note the colours in toned copies or the non-ordered numbering of the original negatives etc., or the content of additional copies that are found at a later time).

Finally, several columns are provided on the right which the print laboratory can use for data relating to exposure (**RGB** for the exposure of the image and the flashing).

Naturally, for the printing of individual fragments, a different exposure has to be used for the various copies, then another for the restored copy or to obtain duplicate negatives or interpositives according to the requirements of the project. To facilitate this, the needed sections could be copied into separate files, and used according to requirements of the project.

21.6.2 Censorship card B24926

The censorship card, issued in Berlin in 1930, gives the text and the order of the intertitles, as well as the original subdivision of the film into six reels.

21.6.3 List of intertitles by Filmliga

By making a comparison with the German censorship card, a difference can be noted between the contents and the caption numbers – obviously Filmliga took great liberty when editing films that it had acquired.

Acknowledgement

Thanks to Mark-Paul Meyer and Nicola Mazzanti for their encouragement and support. (Martin Koerber)

NOTES

1. This chapter is based on an article published in 1998, 'On the restoration of *Menschen am Sonntag'*, *Cinegrafie* (Bologna), No. 11, pp. 262–74. Throughout this chapter Martin Koerber uses the term *restoration* to include both reconstruction of the content, and restoration of the image, although throughout the rest of this book a distinction is made between the two. (Editor)
2. Much more elaborate demands are made in an article by Michele Canosa, Gian Luca Farinelli and Nicola Mazzanti, 'Black on white. Notes on cinematographic restoration: documentation', *Cinegrafie* (Bologna), No. 10, 1997. In fact, here I describe trying to put into practice what they suggest in theory.
3. The Dutch censorship papers survive in the collection of the Nederlands Filmmuseum, Amsterdam.
4. The German censorship card B24926 survives in the collection of Stiftung Deutsche Kinemathek, Berlin.
5. A rich variation of suggestions on how films can be documented for various purposes is offered in Klaus Kanzog, *Einführung in die Filmphilologie* (Ò Diskurs Film, Bd 4), Münich, 1997.

22

The reconstruction of F.W. Murnau's *Faust* (1926): a case study

Faust was reconstructed by the Filmoteca Española, as a part of the Lumière Project, in collaboration with DIF–Wiesbaden, Det Danske Filmmuseum, Copenhagen, and the Budesarchiv Filmarchiv in Berlin.

It was laborious work, which took over four years. It began with a systematic search for the existing copies and negatives in archives and collections all over the world, which took more than a year and involved the inspection of over 40 film prints of *Faust,* and numerous videos, and checking the records of many more copies. From this investigation it was concluded that there were at least five different negatives prepared by Ufa, the German production studio, for the export of the film in the 1920s, and two negatives of the American version, edited in the USA.

Various elements had been preserved: two original nitrate prints, one in Denmark and the other in the Netherlands, three original nitrate negatives in Berlin, and some post-1950 safety positives and negative duplicates.

Only one of these materials, a nitrate print with Danish intertitles, very incomplete and decayed, corresponds to the negative edited by Murnau for the premiere of the film in Germany. The rest of the materials came from the American and French versions, or from safety duplicate negatives made in Germany.

The objective was to reconstruct the best negative, the one edited by Murnau himself in Germany, with the best shots of every scene. However, hardly anything was known about this version, just some newspaper items, which had been published after its only screening for the press in August 1926. The mixed critical reception this screening received made Ufa decide to re-edit the film, revising its intertitles and substituting the accompanying music, both of which was done behind the director's back, as he was preparing for the shoot of *Sunrise,* his next film, in Hollywood. It is therefore assumed that this screening was the only one in which *Faust* was shown the way it had been conceived and edited by Murnau. It was precisely that version of *Faust* we wanted to reconstruct.

We started by researching every documentation source. Neither of the two original screenplays preserved in Paris and in Berlin was the definitive one, since they corresponded to different planning stages that preceded the shooting.

22.1 INTERTITLES

The preserved censorship documents only contained the intertitles, which were produced after production. A few pages of the definitive screenplay were published in the German press just after the premiere of the film in Berlin. By comparing all this information, we deduced which intertitles were prepared by Murnau, and which were the ones Ufa replaced them with after Murnau left Germany to shoot his first film in Hollywood.

We were able to re-compose the original intertitles from loose photographic stills, in poor condition, that were stuck into the French negative and the later German negative as references, and which seem to correspond to at least three different versions mixed together.

22.2 DUPLICATE NEGATIVES AND MULTIPLE TAKES

We were also able to reconstruct the shot sequence due to the fact that Murnau had duplicated the best shots to re-use them in the American negative, which he himself edited later in Hollywood. This American version was very similar to the German version, and included many scenes that were duplicated from the shots that were chosen by Murnau for his German version.

Although the majority of the scenes used in the export negatives were different from each other, because they came from different cameras or shootings, some were duplicates that were also used for export negatives. For example, very complicated trick shots (shots involving double exposure, jump cuts or other camera effects), once they were filmed correctly, were duplicated, at the time, to include them in more than one export negative.

These duplicated scenes are clearly recognizable because of their inferior photographic quality. Modern special effects are rarely produced during shooting, and are generally produced during post-production using special optical printing techniques or digital methods, although sometimes special shots are taken to provide the initial images for these effects. (Thus, the pre-1935 cameramen talked of 'trick shots', whereas today they are called 'opticals' or 'special effects'.)

Until about 1929 a duplicate negative was made using either camera film stock or print film, sometimes a combination of both by copying a cinema print onto camera negative film. This produced a poor, grainy, rather unsharp, high contrast print. Special duplicating films, to make duplicate negatives, were probably first introduced in America by Eastman Kodak (the so-called Lavender film), and were not available to a German film laboratory in 1926.

In 1926 duplicate negatives were therefore of very poor quality. This was precisely the reason why scenes were often shot with several cameras, or the same scene was shot many times. Each repeated scene shooting was, and still is, called in English a 'take', and it seems that as many as eight takes were made of some scenes of *Faust*. Each take produced an original negative, which could be used to make different negative sets of the same version, or different versions of the film for export. They also made it possible to substitute a new take negative for one that had been damaged by handling or during printing, scratching being the most common problem. Takes that were considered of least use, because of poor acting or continuity, or poor lighting or faulty exposure are called 'out-takes' (or sometimes in England 'N.G. takes', meaning no good). It was well known that these were kept too and pressed into service when all the best takes had been used up.

In 1926 most original negatives were kept in either single scene rolls or in rolls of scenes that were destined for the same tint or tone treatment. A final complete cinema print consisted of these sections of print joined together, and the process was called 'pos(itive) cutting'. Not all film was handled this way in 1926, but the negatives of *Faust* were probably not all joined together in the modern manner.

Today all the selected takes of original negative film is cut into a single, sometimes two A&B, rolls and duplicate negatives are made from this. The duplicate negatives, which have no splices, are then exported. Duplicate negatives are made of all widely distributed films and these duplicates are used to produce the cinema prints rather than risk damage to the original negative. Duplicate negatives can also be sent to other countries where prints are made for exploitation. In the 1920s, the usual system was to edit or cut different original negatives into versions that were sent to other countries for printing. They remained there for the duration of the distribution deal, after which they would be returned to the production company, who stored them or patched them up for other purposes, combining with other worn out negatives to make the best use of them and achieve the best financial return.

Many of the export negatives of that time have come to us as fragmentary hybrid combinations of re-used negatives.

22.3 VERSIONS OF *FAUST*

In the American version, there were also many other scenes shot specifically for it, in particular all those that showed books or texts, which in the American version were in English. The Danish version had most of these scenes with books or texts in German.

In the contracts signed in 1925 between MGM (Metro Goldwin Meyer) and Ufa it was specified that the German company had to send 'the uncut original camera negative' of every one of their films which were distributed by MGM so that they could be edited in the USA.

Murnau accepted this clause on the condition that he himself would cut the negative in Hollywood. It is thanks to this that the original takes of his cutting came to us, because he took original camera negatives with him to America, leaving the duplicates in Berlin.

The German version was therefore edited using inferior duplicate negatives and inferior takes, and the indignant Ufa executives did not hesitate to substitute these negatives for others if they could. The inferior quality of the duplicate negatives used for the first German negative is clearly recognizable in the Danish copy, the only one taken from this negative that has been preserved.

22.4 THE RECONSTRUCTION FROM ORIGINAL NEGATIVES

We had access to fragments of eight different original negatives and these materials enable us to study in detail the shooting techniques of Murnau and his decisions on the set.

These negatives contain every type of shooting mistakes, and in the case of *Faust* probably correspond to stages in the development of the complex and *avant-garde* effects, so abundant in the film. The takes from the first imperfect shoots were used in the editing of some of the export negatives meant for countries which were considered of secondary importance by Ufa.

It was also important to demonstrate that in the silent era very different negatives were being edited for export purposes with takes from different cameras filming at the same time or from successive shootings. Takes from four or five different negatives showed the enormous difference in quality, staging or rhythm, demonstrating that the same film was shown in completely different versions at premieres in Germany, France, England and the USA. It became clear that Murnau took advantage of five or six takes to continuously alter the take action, changing the rhythm, the lighting or the interpretation, or to try out different forms of staging for the same scenes. It was also clear that he repeated days of shooting while making radical changes in his conception of a scene.

The reconstruction is based on the original takes and original negatives, and their photographic quality is excellent in most of the scenes. These were first taken to Hollywood, and later returned to Berlin. With scenes taken from at least seven different origins it was possible to solve the puzzle and to reconstruct the first negative. This was also thanks to the excellent photographic reproduction done by the Italian laboratory L'Immagine Ritrovata in Bologna. In some scenes it was necessary to join fragments from very different sources in order to reconstruct an entire shot.

A similar job was needed to reconstruct the accompanying music, prepared in 1926 by Paul A. Hensel. His list of 78 musical themes was published in a Berlin newspaper a few days after the premiere of the film. We carried out a comprehensive search in musical archives all over the world with the help of the Goethe Institut and of the specialists Theodore van Houten and Berndt Heller. In collaboration with the Spanish musicians Armando and Carlos Pérez Mántaras, they arranged an orchestral version from the available documents.

Finally, during the Berlinale of 1996, the reconstruction of the original version of *Faust* as edited by Murnau was screened, together with the original musical accompaniment. This version had not been screened since 1926 and it is very different in its rhythm, staging, acting and photographic quality, to the versions that have been seen in the past few decades. There was great satisfaction in being able to rescue the original version of this wonderful and spectacular film by Murnau, with its gamut of greys and its primitive photographic quality.

The work on *Faust* is continuing and will eventually catalogue the many other pieces of data the film materials can provide. These include print film edge marks, edge marks printed in from the original negatives, negative cutter's notes, printer marks, marks from the developing machines, frame lines (both those of the printer and those printed from earlier elements), chemical and polishing treatment marks on the film base, and the splices. Numerous indications exist on the original nitrate that can give us clues to understand the origin and the primitive form of editing that was used to produce the various versions of the film.

22.5 THE IMPLICATIONS OF FOREIGN VERSIONS FOR RECONSTRUCTION

It is important to recognize that the system of editing negatives for foreign countries is not exclusive to *Faust,* even to the films of Murnau. There seem to be five different negatives of *Der letzte Mann,* at least three of *Herr Tartüff*. All German films of that time were similar – different negatives have been identified of films by Lang, May, Pabst, Robison, and of all the European and American silent films. There are copies of *Sunrise* by Murnau, shot in 1927 in Hollywood, from two totally different negatives.

Many silent films that have been restored have been based on prints found in countries other than the production country. These prints were made from export negatives, which were normally inferior takes, and therefore not those made from the best original negative. It is through these, sometimes horrible, copies of that we judge these works and directors.

It is clear that from the establishment of this fact that it will be necessary to revise all the existing materials of other films by Murnau and by other directors such as Fritz Lang. In future every restoration will have to be documented, in order to specify which version has been restored, and to document the variations that occur between the various export negatives.

22.6 VERSIONS MADE FOR LATER RELEASE

Even the exhibition of a film in its original country does not guarantee that it came from the first or best negative. In the case of *Faust*, Ufa afterwards edited together negatives of various versions. One of the preserved negatives of *Faust* contains takes that originally were chosen from takes nos. 3, 5, 6, 7 and 8. This is easy to demonstrate because the various scenes still have the editors indications in ink, and they clearly show the number of the negative and the number of the take (a number that did not coincide with the cut negative version). In a later negative of *Faust* some scenes were polished to eliminate scratches. These came from a cut negative that had been broken down into sections after it was scratched, a common problem when being used to make a large number of prints.

The very last negative that was put together contains takes of the utmost lowest quality, sometimes even out-takes were kept in case this was necessary.

Ufa made a version in the late 1920s in order to have a clean negative at their disposal, without scratches or damages, from which they could make further duplicate negatives or prints. For example, from this negative they made 9.5 mm Pathé Baby prints. However, in order to put it together, they destroyed the best negatives, including those edited by Murnau. It was considered unusable because of the damage it had suffered when so many prints had been made.

This is not an isolated case. The original negative of *Der letzte Mann*, preserved in Berlin, is also a later re-assembly of an earlier version. This included scenes from the American cutting broken down by Ufa after its return from Universal Studios to Berlin once the term of US agreement had expired.

22.7 CONCLUSION

We have lost the best negatives and prints because they were the oldest. Many films are only preserved as prints made from re-assembled cut negatives. Some of these include out-takes and takes of very poor quality, and prints from low quality early duplicate negatives.

The preserved silent film finds itself in a much more dramatic situation than we thought it to be. The work done in the restoration of *Faust* to identify the origins of the various takes, and the destiny and antiquity of each negative, has significance for all the works of the great directors of silent films.

Every reconstruction done reinforces the need to keep all the original nitrate materials. Unless they are kept, the images and the information they provide cannot be revisited or reassessed. Even if they are well duplicated, the originals are full of valuable information that make it possible to reconstruct the history of the elements, and help to clarify which were the original materials, and which was the original version.

23

Film bases and tests

Cinematographic film is made up of a film base, coated with one or more emulsion layers that contain the photographic image. The film base should be transparent, and – to be usable in cinematographic equipment – at the same time flexible and strong. The synthetic plastics that were invented in the late nineteenth century could meet these requirements. Unfortunately, the first film base was highly flammable and some is chemically unstable over longer periods of time. Over the years research provided safer and more stable compounds. However, no material is totally satisfactory. All of them can be damaged by the usual routines of handling and almost all suffer some sort of deterioration by time.

23.1 CELLULOSE NITRATE

The first successful film base was Celluloid, a mixture of cellulose nitrate and plasticizer. It was invented in the USA in 1870 and first used as a photographic base in 1889. Celluloid was the first synthetic plastic. It was thermoplastic, very tough, with a high tensile strength, and could be handled mechanically somewhat like a metal. It could be polished, dissolved in an organic solvent and easily modelled. Celluloid was produced from cotton waste or wood pulp, treated with nitric acid. The plasticizer, camphor, eliminated the brittleness. It was used for a wide range of products, from gun cotton to toys and telephones, as safety glass as well as film base. For this purpose the dissolved material was laid down in thin sheets, that could be slit and perforated to the required size and shape.

Almost all 35 mm film produced from 1896 until 1950 was cellulose nitrate. Eastman Kodak discontinued the manufacture in 1951, and in the next three years nitrate cellulose was replaced by cellulose triacetate in most parts of the world. In China and the Soviet Union nitrate cellulose was used until the 1960s, and some laboratories used old stocks of nitrate cellulose for leaders during the 1950s and early 1960s.

23.1.1 Inflammability

In many ways cellulose nitrate film provided all the requirements that were needed for cinematography. However, it has two major weaknesses: its inflammability and chemical instability. When ignited, cellulose nitrate burns with an intense, explosive ferocity. Most nitrate fires were in cinemas and laboratories where the ignition occurred in projectors. If the film stopped in the projector gate the heat from the projector lamp ignited the fire, unless a dowser, an asbestos shutter, dropped between the lamp and the gate. Burning reels of nitrate produce their own oxygen and will continue burning when covered with water, sand or foam. Laboratory tests, carried out by the FIAF Technical Commission, showed that nitrate cellulose will not ignite under a temperature of 160°C (320°F). The apparent cause of so-called 'spontaneous ignition' is an accumulation of heat within film reels, that can start building up in hot weather conditions, with external temperatures over 40°C (104°F) (from: *Handling, Storage and Transport of Cellulose Nitrate Film,* FIAF Technical Commission).

23.1.2 Decomposition

Nitrate cellulose is chemically unstable, which results in the release of heat and nitrogen oxides. These gases start the process of decomposition. The initial signs are severe shrinking, up to 5% in length, but chemical decay can also occur well before serious shrinkage is obvious. The first visual sign is a cloudiness of the base, thickening of the film, and brown powdery deposits, especially from the film edges. The characteristic, aromatic smell of nitrate cellulose increases. Later on the gases affect the photographic image, and the film convolutions starts to stick together and exuding almost liquid blisters. Eventually the film may set in a block and disintegrate into a little pile of brown powder and an acrid odour. It does not seem that the material becomes more inflammable during decay, and in the final stages it may even lose its inflammability. One reel of nitrate may show signs of different stages of decomposition. The progress of the decay is dependent on temperature and humidity. As the process cannot be stopped – proper storage can only slow it down – the only way to rescue a decomposing film is immediate duplication.

23.1.3 Ageing tests

The onset of nitrate decay can be detected in early stages before the composition is visually noticeable. This is done by chemical tests, known as accelerated ageing tests. The most frequently used is the Alizarin Red Stability test. A punched out piece of film – approximately 6 mm in diameter – is heated in a test tube with an indicator paper, that is drenched in a Alizarin solution. According to the stability of the nitrate sample the indicator paper changes colour.

As tests like this are worked out on a regular base, it is possible to detect and duplicate the unstable films before they show signs of decomposition. Apart from early detection of films that should be preserved, the stability of a collection of nitrate films can be followed in detail.

23.2 'SAFETY BASE' OR ACETATE

Since the beginning of the motion picture industry, research was carried out to find a safe alternative for nitrate cellulose. As early as 1909 a less flammable film base was developed, cellulose diacetate. However, it was not widely used. 'Safety film' only became the standard for 35 mm film in 1951, when Kodak switched their production to cellulose triacetate film, an improved acetate base. By far the largest amount of films in archives has a cellulose triacetate base.

Polyester film was introduced in the 1960s for films where high degrees of dimension stability were required, for example in the graphic arts industry. This chemically stable and very strong base became common for some cinema release prints during the 1970s and is still used today.

23.2.1 Cellulose diacetate

This early safety film base was produced by Eastman Kodak from 1909, but was not widely used. Acetate film is made from wood pulp or cotton liners, treated with chemicals and solvents. The first materials needed a lot of solvent, and as this solvent evaporated it shrank badly. Also it was more expensive to produce than cellulose nitrate. Cellulose diacetate is still inflammable, although by comparison with nitrate cellulose it burns slowly and lacks the explosive ferocity. It was mainly produced for narrow gauges, especially for the home market, where projectors were common without a booth. In 1923 Kodak used it for the first 16 mm film. In the 1930s quite a number of special 35 mm films – notably Dufay film stocks – were made on a diacetate base.

Cellulose diacetate does not last well. The early stocks lost plasticizer easily and shrank quickly into brittle, curled fragments. Provided the film is in one piece, the film can temporally regain its flexibility by a chemical deshrinking process, and can be printed. However, even the best storage conditions are said not to save cellulose diacetate from destruction, and it is as sensitive to vinegar syndrome (see below) as cellulose triacetate.

Some film bases are described as 'mixed esters' and contain cellulose butyrate or propionate with cellulose triacetate (e.g. early Kodachrome film). These bases also decay as all acetate bases do, although less is known about them.

23.2.2 Cellulose triacetate

During the 1930s the first cellulose triacetate bases were developed by Eastman Kodak and Gevaert. The material needed less solvent than diacetate cellulose, but was still not comparable with nitrate cellulose. The breakthrough came in 1948, when a formula was found which had similar optical and mechanical qualities as cellulose nitrate. In 1951 most inflammable film was replaced by cellulose triacetate, widely known as 'acetate' or 'safety film'.

Cellulose triacetate can still be burnt, but requires high temperatures to ignite. It is thought that some cellulose nitrate fires have been made more serious by the presence of cellulose acetate film that burns less easily but for longer.

The material is subject to shrinking, although to a lesser extent than nitrate cellulose and diacetate. The most disappointing quality, however, is a serious chemical decay in time, known as 'vinegar syndrome'.

23.2.3 Vinegar syndrome

Vinegar syndrome was first reported in the late 1950s in films that had been stored in a hot, humid climate. It is caused by hydrolysis of plasticizers into acetic acid. These acids accelerate the process of decomposition, and give the film its characteristic vinegar odour. First sign of vinegar syndrome is this smell, and it can take some time before visible damage can be found: extreme shrinkage, dye fading and deformation of both emulsion and base. Eventually the bond between emulsion and base gives way, the emulsion buckles up, and the base seems to melt away or char to a dark, crisp mass.

As the problem grows – most archives hold large amounts of cellulose triacetate – knowledge of the appearance vinegar syndrome is getting more detailed. Vinegar syndrome has been seen to be influenced by the presence of iron, like rust particles and iron oxide magnetic sound tracks. Sound track films such as sprocketed magnetic tape and COMMAG 16 mm colour news film (Common Magnetic – which have a magnetic sound stripe applied during manufacture) are more prone to decay than conventional film. Varnished and coated films and certain manufacturers' films are also reported as being more at risk than others.

23.2.4 Control of vinegar syndrome decay

As high temperatures and humidity promote vinegar syndrome decay, proper storage is the most important aid to prevention. Lowering the temperature and humidity will greatly extend the life span of triacetate film. When vinegar is detected, the film should be brought to a different storage room, to avoid the acids affecting other films.

A number of techniques have been devised to detect vinegar syndrome, and others to remove the acetic acid from the can, as the presence of acetic acid acts as a catalysis and promotes further decay. Indicators can be helpful to detect vinegar in an early stage and monitor the development of the process. These, like A-D strips from the Image Permanence Institute, and the products from Dancan (Denmark) and BTT (Germany), consist of small strips or buttons, that are inserted in the can. The colour of the indicators changes according to the amount of acetic acids in the can. Testing can be helpful to manage the vinegar syndrome in collections: according to the results serious cases can be selected for duplication, or further monitored in isolation.

Other devices – like Kodak Molecular Sieves – can be placed in the cans to remove the acids. These special bags or small chemical containers absorb acids from the can and their surrounding environment. These systems are effective but seem less suited for larger film collections, as the cans have to be checked on a regular base to replace the saturated containers.

23.3 POLYESTER BASE

Polyester was invented in 1941 and the first films with polyester base came on the market in the 1960s. It is a petrochemical product, known by trade names as Kodak 'Estar' and 3M's 'Mylar', and is also often referred to as 'Ester' base. It is by far the most stable and resistant film base. Compared to cellulose triacetate it is less flammable, chemically stable, and less sensitive to shrinkage and other changes over time. The expected life span of a polyester film is very long, and has many advantages over cellulose triacetate film. However, one should bear in mind that the life expectancy of the emulsion – which holds the photographic image – could be much shorter than the base. Today polyester base is used for some release prints, some archival materials and Super 8 films, where its strength helps to reduce the risk of film damage.

It is not possible to break polyester film by hand: scissors must be used. Once nicked at the edge, it can be torn by hand, a little unwillingly, and leaves a sharp jagged cutting edge. Polyester base also cannot be cement-spliced like other film bases, and joins should be made with tape splicers or special heat-splicing devices. Polyester is so strong that accidents – like a film getting stuck in the printer – can lead to serious damage of cinematographic equipment. Equipment for handling polyester base is designed with this in mind, like Super 8 projectors with only a single sprocketed drive roller. Old equipment, which is designed for acetate bases, should be used for polyester with care.

23.4 IDENTIFYING FILM BASES

Usually, the first thing to look after when a film enters an archive or laboratory is the film base. Separation of nitrate films from safety films is important for storage and safety reasons, and identification of polyester is important for handling. The separation of cellulose triacetate from cellulose diacetate is not essential – and very difficult – as there is no need for different storage. Be aware of the possibility that safety films have nitrate leaders, and vice versa, and different film bases can be spliced together on one reel. The first things to check is the information on the can and the film edges.

23.4.1 Edge marks

Safety film is generally marked 'safety' or 'S'. In rare cases this edge mark might have been copied onto a nitrate film from a previous generation.

Kodak nitrate cellulose films are marked 'nitrate film'. Polyester films do not have a 'safety' edge mark: some stocks are marked 'Estar' or 'Corner'.

23.4.2 Gauge and period

In many cases the period and the film format give an indication of the possible film base. Films produced after 1951 are seldom released on a nitrate cellulose base. 35 mm films produced before 1951 almost always are. An original full frame 35 mm film – without an optical sound track – is almost certainly a nitrate film. Narrow gauges like 16 and 8 mm film are safety film, as nitrate film is almost never any other gauge than 35 mm.

When no information whatever can be found, or there is serious doubt about the film base, a test can be done. There are many identification tests; a description of the most common is given here.

23.5 TESTS TO IDENTIFY NITRATE CELLULOSE

In general it is recommended to perform tests on known materials for comparison. One should keep some labelled pieces of scrap film – nitrate, acetate and polyester – and carry out the test on the known samples before testing the unknown sample. This reduces faults due to misinterpretation or degenerated test solutions.

23.5.1 Burning test

Nitrate film ignites easily and burns quickly with a yellow flame. Acetate burns slowly and needs time to ignite. Carry out this test on a small piece of film – at least half a frame – that is bent and put vertically in an ashtray or hold up with a metal tong. Ignite the sample from the top, as only nitrate cellulose will burn downwards. Do this test in a safe place. Polyester burns least well, melting and charring first.

23.5.2 Ultraviolet test

Some film manufacturers, such as Kodak, incorporate a fluorescent chemical into the base of safety film, which lights up under ultraviolet light. As other acetate stocks do not contain a fluorescent agent this test is not exclusive.

23.5.3 Floating test

Nitrate film sinks in trichloroethylene, while acetate film floats. Polyester is about the same density and tends to remain in the centre of the solution. Use a small, dry punched out section of film, placed in a test tube. Shake gently, to make sure the sample is immersed. This test is said not to be completely reliable, as the specific gravities for cellulose nitrate and cellulose acetate fall within a broad range, which may cause materials to behave differently. As trichloroethylene is toxic and carcinogen, it should be handled with extreme caution.

23.5.4 Amyl acetate test

Cellulose nitrate can be partly dissolved in amyl acetate, leaving a disintegrated deposit. Acetate is unaffected. Try this with a small drop on the backside of the film, which is wiped off after a few seconds.

23.5.5 Diphenylamine test

A drop of diphenylamine in concentrated sulphuric acid (10 g/l) turns bright blue on cellulose nitrate, and has no colour effect on acetate bases or polyester. Carry out this test with a small drop on the backside of the film. After one minute the solution on the nitrate sample will turn blue. In some cases a sample of nitrate may exhaust the solution. Therefore, to confirm a negative test, a second test should be carried out on the same sample.

23.6 TESTS TO IDENTIFY POLYESTER FILM

23.6.1 Polarization test

When viewed between cross-polarized filters, polyester exhibits green and red interference colours. Nitrate and acetate films do not show these. This test can be performed with a simple viewer. Place a piece of film between the filters and hold it up to a light source. When tilted up-and-down the green and red interference colours will be visible. Polarizing filters are available at toy stores in 3-D glasses or science kits. A simple viewer can be made of two pieces of cardboard, with holes to put the filters in.

23.6.2 Strength test

Polyester film cannot be broken by hand. Both cellulose nitrate and acetate can.

24

Deshrinking and other treatments

24.1 DESHRINKING

The deshrinking process was common in some laboratories but times are changing, and concern over the long- and short-term effects on the film of these chemical methods means that deshrinking procedures are rarely used today.

The procedure has been unfortunately clouded by several commercial mixtures given near magical properties by their developers, but the basic process is fairly straightforward and simple to perform. Take a piece of shrunken film – no need to unwind it – just stand it on a metal support over an open tray of acetone in a closed container in a warm place. An ideal container is a large glass or aluminium cooking pan with a lid. In a few days, or a few weeks, depending largely on the temperature, the film will expand and achieve almost its original size and can be printed on most conventional printers.

There are a lot of little practical difficulties. Acetone is unpleasant to handle, inflammable and evaporates quickly, and once you have taken the film from the acetone vapour you may need to *run* to the printer before the film shrinks back again! Nevertheless, the procedure works, and it is applicable to both nitrate and acetate film base.

Several extra chemical components have been added to the acetone and some mechanical complexity has been added to this basic process to make it controlled, safer and a little more permanent, but unfortunately the process has not become any faster or more effective.

1. A 1:1:3 mix of acetone, glycerol and water and the film are usually kept in a closed metal container. Months at 10°C or weeks at 30°C may be needed. Winding the film through a few times helps.
2. The process can be accelerated, especially for large rolls, by placing the roll in a reduced pressure (down to 30 mm Hg), preferably heated to about 25°C and held at this pressure for several days. Large rolls relax considerably and can then be extremely difficult to handle.
3. Sometimes the basic acetone is supplemented with Camphor (a plasticizer for nitrate film) or a methyl phthalate (plasticizer for acetate film) and the rate of reshrinking is slightly reduced. The following formula is used for nitrate film:

Glycerol	200 ml
Camphor	30 g
Acetone	to 1 litre

However camphor may have a deleterious effect on the film base life and sometimes crystals of camphor start to form in the base and on the surface. Consequently it must only be used when the film cannot be printed any other way.

24.2 REHUMIDIFICATION

Emulsions become brittle due to loss of water and may also shrink more than the film base, producing a cracked image. Occasionally the emulsion flakes off. A widely practised technique is to stand the film roll on a support over water. This is very effective, although it may take weeks in low temperatures before the cracked flakes appear to link up. Occasionally at high temperatures mould begins to grow on the emulsion and a little formaldehyde (less than 0.5%) in the water will prevent this. It has been reported that the film base may be similarly rehumidified as the film does seem to deshrink under these conditions, and certainly becomes more flexible and less brittle.

24.3 THE REDIMENSION, VACUUMATE, REHUMID, AND NO-EN PROCESSES

These commercially available processes were devised and franchised by Restoration House in Canada over 30 years ago specially for use on archive film, and a few commercial laboratories still use them.

24.3.1 Redimension

This is a mixture of various solvents and plasticizers in acetone, and is undoubtedly effective. It has been for many years but has now been replaced by the faster and much simpler solutions above.

There are problems with Redimension which make it difficult to use. Film archives today need to be sure that any process their film is being put through will not impair the film or the image life, unless they are sure that there is no other way. Redimension is always said to have no effect on the film life but there is no evidence one way or the other, and without the published formulae (restricted under the franchise agreement) the facts cannot be independently checked.

The process does not seem to be suitable for vinegar syndrome film unless the film has been cleaned first to remove the sticky surface and crystals that form on the base, and in general vinegar syndrome film needs quite different treatment. Very little investigation has been carried out on treating vinegar syndrome film to assist printing.

24.3.2 Vacuumate

The process used low pressure vessels and several stages of vapour treatment to suffuse the film with cocktails of hardeners, fungicides, oils and lubricants. The process was designed to effect changes to the gelatine of the film emulsion in order to increase the useful life of a film. Some components had no, or virtually no, effect. Others like acetaldehyde were very effective emulsion hardeners and fungicides but are extremely unpleasant to handle and subject to strict safety requirements. The films processed was effectively lubricated by the oils but this can be achieved by simpler procedures.

Whether the film life was really improved is difficult to judge, although films destined for the tropics were certainly made more resistant to fungal and bacteria attack. Vacuumate does have some deshrinking effect since one solution contained acetone.

The Vacumate process, with comments in parenthesis from Restoration House literature, is as follows:

- Solution 1 Acetaldehyde (reduces the excess moisture from processing).
- Solution 2 Turpentine, various natural oils and 1,1,1 trichloroethane (conditions the base and emulsion, providing protection against drying and brittleness).
- Solution 3 Acetaldehyde, isopropyl alcohol, water and oils (hardens and toughens the film's emulsion).
- Solution 4 1,1,1 trichloroethane, paraffin wax and oils (provides a permanent lubrication, ensuring that the film remains supple).
- Solution 5 The same as solution 4 plus a mineral oil (provides an additional external lubrication for release prints to be projected).

Today the use of 1,1,1 trichloroethane, a CFC, is restricted by the Montreal Convention. Perchlorethylene is used instead, but is less effective.

24.3.3 Rehumid

Again used in a vacuum chamber, this process was designed 'to replace the loss of a film's water content with a less volatile agent'. It is effective in making cracked, brittle and shrinking emulsion more pliable. The agent was kept a secret, but seems to have been another cocktail of solvents and plasticizers. Rehumid was advertised as a technique for processing film that had not undergone Vacuumate treatment prior to a lot of projection or long storage. The same process can also be carried out by storing film in a humidity of 90%, for example by storing film rolls in a container over water, and this is much less likely to cause future storage problems. Rehumid was certainly fast but water could be used in a vaccuum chamber to give the same effect.

24.3.4 No-En

This too was a vacuum chamber process in two stages said to restore 'loss of moisture and create a perfect running surface'. The process seems to have many features of Vacuumate and also included a wax. After processing the film was usually mechanically buffed to provide glossy polished edges and surfaces.

24.4 CONCLUSION

Recent changes in film handling equipment have made many of these chemical processes virtually redundant. Specialist printing equipment for archive film no longer needs film of exactly the standard pitch between the perforations.

There is still a case for deshrinking and rehumidification in archive preservation when no other technique allows the film to be printed or unwound. Simple components such as acetone for deshrinking and water for rehumidification seem to be better than complex mixtures.

Waxing and lubricating processes may always be needed for film that will be projected repeatedly, loops and cassette machines for example, and these too use simple solutions. The low pressure vacuum chamber is a faster method than standing the film reel over an open tray of liquid but is essentially no different. Anti-fungal treatments, such as Vacuumate, are effective but most colour print film processing uses a preservative solution as the last stage.

25

Scratch treatments

25.1 EMULSION SCRATCH TREATMENT BY REWASHING FILM

Rewashing is a term that was used for the very common process of running processed film through ***a complete developing process*** for a second time. This removes dirt and heals slight emulsion scratches. In general this is not thought to cause problems to the image or its stability, except in the case of some modern (say post-1955) colour films, but tinted and toned films should be tested first to see whether the dyes are removed. Most or all toned films seem to be resistant to washing but some tint dyes do wash out.

The following solution has been used for many years to rewash black and white film and is very effective as an alternative to reprocessing the film entirely through a normal process (and cheaper):

25.1.1 Re-washing formula

- Stage 1 — Rewash Solution: 50 g per litre of sodium sulphite, 50 g per litre of borax. A high pH is essential. Concentration and temperature is not very critical. Process temperature: 20°C.
- Stage 2 — Wash for 10 minutes at 20°C.
- Stage 3 — Final rinse stage of 1 minute at 20°C in a 500:1 Photoflo solution to help uniform drying.
- Stage 4 — Dry.

25.1.2 Kodak Rewash RW1

Kodak colour negative films are reported to suffer an increase in green density after repeated re-processing. This is probably true of all modern colour films. This is said by Kodak to be minimized by omitting the developer and/or the bleach from the 'rewash' process. It is also essential to use the correct final rinse in order not to impair the life of the dyes. Kodak has published a procedure, Rewash RW1, to avoid these changes and at the same time to produce similar emulsion swelling, which occurs in the developer and heals scratches.

- Stage 1 — Prebath PB-6 and its buffers (as normally part of the ECN-2 Process). 21°C for 2 minutes with a recirculation rate of 20–40 l/min. Swells the emulsion, causing the scratches to be annealed and embedded dirt particles to be released and buffed off.
- Stage 2 — Wash. 31–38°C. 3 minutes with a wash rate of 300 ml/min.
- Stage 3 — Final rinse. 21–38°C. 10 seconds with a recirculation rate of 20–40 l/min.

The final rinse today would be the final rinse solution used as the last solution in the modern ECN-2 process FR-1. However, in principle the final solution should be the original final solution or stabilizer that was used in the original process if this is known.

For the treatment of old colour films the same solutions can be used, and little difference in effectiveness on scratches has been found between the two formulae above. A final stage is always needed to preserve the future stability of the dyes. Ideally this should be the solution that was used in the original process for this particular film stock. This requires identification of the film stock and knowledge of the original process. Some of these solutions consisted of pH buffers and a wetting agent, some were formaldehyde or solutions with specialized stabilizer chemicals. If no information is available the formula below can be used. This solution was used in many colour processes between 1960 and 1990, certainly on all reversal colour films and all colour print films.

25.1.3 Final rinse

If the process originally used is not known the following formula can be used for re-washing colour films (1 minute at 21–28°C):

Formaldehyde 37%	10 ml
Wetting agent (e.g. Photoflo)	5 ml
pH adjusted to	4.0
Water to	1 litre

25.1.4 Equipment

A custom-made processor may be used solely for rewashing, or a conventional processor may be modified so that an alternative film path is easily created. This may use just two solutions and a wash in the case of the Kodak colour film Rewash RW1 process, using an ECN-2 or ECP-2 processor. Most commercial laboratories do this, and may offer it as a service. Always check what the laboratory will use for this process and do not use complete reprocessing for colour films.

Alternatively, a special additional tank may be inserted in the sequence of a black and white processor.

25.2 BASE SCRATCH TREATMENTS

These treatments, using acetone to dissolve and reform the base surface on a smooth glass surface, are mentioned in Chapter 11 on film repair. They are rarely used today since wet gate printing makes the process unnecessary.

26

Film cements

The following cements can be used:

26.1 CEMENT FOR JOINING NITRATE FILM

(for 1 litre)

Acetone	0.66 litre
Amyl acetate	0.33 litre

This cement is adequate for hand joins. For machine joins increase the viscosity by dissolving some nitrate film base in the acetone and filter before adding the amyl acetate.

26.2 CEMENT FOR JOINING ACETATE FILM

(for 1 litre)

Clear acetate film base	10 g
Acetone	0.30 litre
Methyl chloride	0.30 litre
Methyl glycol acetate	0.30 litre
Phthalic acid, dimethyl ester	100 g

26.3 CEMENT FOR JOINING ACETATE TO NITRATE FILM

(for 1 litre)

Clear acetate film base	35 g
Acetone	850 g
Glacial acetic acid	30 g
Camphor	115 g
Triphenylphosphate	6 g
Phthalic acid, dimethyl ester	25 g

26.4 CEMENT TO JOIN ANYTHING TO ANYTHING (IN DESPERATION) (EXCEPT POLYESTER)

(for 1 litre)

Acetone	0.50 litre
Amyl acetate	0.25 litre
Glacial acetic acid	0.25 litre

Warning! This cement contains noxious acetic acid and should be removed thoroughly from the splicing equipment as it corrodes metals very quickly.

27

Printers for shrunken film

27.1 DEGREES OF SHRINKAGE

One of the most common effect of time and temperature is for the film base to shrink overall due to a loss of plasticizer.

Cellulose nitrate film base can shrink by up to 3% without serious decay, although usually the base is decayed after 2%.

Shrinkage on acetate films is up to about 2% before serious decay, although shrinkage of 5% (with severe brittleness) has been recorded on diacetate film, and 10% has been recorded on vinegar syndrome decaying cellulose triacetate.

In both film base types shrinkage of the film base occurs before any other major change. Whatever the effect storage has on film it is always associated with some shrinkage, caused usually by the loss of plasticizer (and perhaps other effects) from the film base. The effect is not consistent and it is common to find 50-year-old film shrunken but still quite supple and not in any way brittle, and plasticizer loss may not be the only cause of shrinkage.

Shrinkage has two effects on the process of restoration of the image. First, beyond a certain shrinkage it is not possible to print the film, although different printers can handle different degrees of shrinkage. Secondly, the image becomes smaller and eventually it is significantly smaller than the original frame.

Shrinkages of 5% can occur without the film suffering from severe decay or brittleness, but this much is uncommon. Most film has decayed beyond recall at lower shrinkages. A lot of 70-year-old nitrate film is 2.5% shrunk and a lot of 30-year-old film is 1.5% shrunk. Most film shrinks more or less uniformly, but both severe tension in the roll or lack of tension in the roll seems to increase the likelihood of edge wave, spoking, cockling, buckling or fluting, those splendidly graphic terms for local curls and unevennesses of old film. The degree of shrinkage varies between film stocks and between batches of the same stock as measurements of different shots in a film reel will show. Sound film is often more seriously shrunken than the negative film paired with it and intertitle film is often more shrunken than the image print on either side.

27.2 PRINTING METHODS

The following methods exist for printing shrunken film:

1. Use a printing (or telecine) unit that does not use on the perforations for film transport.
2. Make new film transport mechanisms for the shorter pitch between perforations for an optical step (or continuous) printer projector head – this may also mean replacing the register pins or the entire film pull down mechanism.
3. Use a worn out sprocket drive mechanism of a rotary contact printer, or, on a worn down step contact printer, or remove the register pins.
4. Treat the film in a 'deshrinking' process to restore the film to within the range a conventional unmodified printer can handle.

27.3 PRINTER MODIFICATIONS

Most 35 mm printers cannot tolerate shrinkages greater than 0.3–4% before they become noisy and start to damage the film perforations. Before that point the image jumps unevenly. On rotary contact printers the raw stock tends to slide against the archive film producing an out-of-focus image. Eventually either the film is torn as the sprockets or pull down claws miss the perforations altogether.

The classic method of handling shrunken film is to change the drive and pull down mechanism, and on an Oxberry, Neilson–Hordell, or any of the older step optical printers this is reasonably easy. On a rotary printer the main sprocket drive by the gate must be changed and often many other rollers as well. The problem has always been that the range of shrinkages then possible is still quite restricted, usually to about 0.6–8% at most, so that probably three or four different drive assemblies are needed to go from 0% to 3%.

Some recent printers can handle shrunken film to a much greater extent than ever before, and not just because they are designed to do this.

Variable pitch pull down mechanisms can be fitted to several of the standard optical printers, but only the Sigma continuous contact printer (used by the NFTVA in the UK) and the Debrie TAI have been offered for sale as a routine. Both are liquid gate printers. The Sigma has not been all that successful, probably for other reasons than the drive mechanism, and only the two in London were ever built. The Debrie TAI has existed in several different archive versions over the years has become the main archive optical printer. Speeds from 4 frames per second up to 16 or 20 frames per second (60 or 75 ft/min) are possible if the shrinkage is even.

Another quite different approach is to use a rotary printer that avoids the large number of sprocket rollers and uses a drive that approaches the capstan drive of an editing table or a telecine machine. Such a printer is the BHP Modular that can be used wet or dry and has a far wider tolerance of shrinkage. The range seems to be about 0–1.3% and after that point the slippage begins to be visible to a very critical eye but the drive mechanism seems to cope up to about 1.8%. After that the film jumps and the single gate sprocket skips perforations. The BHP drive system was chosen to be simple, not in order to handle shrunken film, but it seems to fill an important gap in the equipment. Not unimportant is the fact that the printing speed far exceeds any other printer for the shrinkage it can handle, and speeds of 160 ft/min or more are common for 1.5% shrinkage film. The image quality and steadiness of this printer with shrunken film has surprised many technicians.

Table 27.1 shows a range of printers that have been used for printing shrunken film. The information is from private files and also from a survey carried out by FIAF in the early 1990s.

There is still a gap in the scale as we know it today. Shrinkages over 2.5% are difficult and slow to print even on a Debrie TAI, but worse still are uneven shrinkages, where different stocks varying in shrinkage from 1.5% to 2.5% or more are cut together. The splices are the most difficult positions, probably because the film is less flexible at these points.

27.4 TELECINE UNITS

When old film is transferred to a video signal there are fewer problems with shrunken film than on a printer and perhaps printer manufacturers should look at the drive mechanisms of telecine machines. A telecine is a continuous drive, and an unmodified Rank Cintel or Philips Spirit can handle from 0 to 2.0% shrinkage, with difficulty at some splices.

(A conventional optical sound follower used with a telecine can normally only cope with 0.6% shrinkage. The quality of a sound negative reproduction by this method is poor in any case and usually it is better to make a positive print which would overcome the shrinkage and the lack of cancellation.)

Table 27.1 Printers used for shrunken film and their reported characteristics

Lab or archive	*Make*	*Model*	*Type*	*Speed fpm/s (min)*	*Speed fpm/s (max)*	*Speed ft/m (max)*
L	Arri	no data	step opt	4 fps	12 fps	20
A	B&H/Schmitzer	Mod C	rot cont cont	60 fpm	80 fpm	60–80
A	Debrie	TAI	step opt	5 fps	30 fps	18–110
A	Debrie	TAI	step opt	5 fps	25 fps	18–94
A	Debrie	Matipo	step contact	12 fps		45
L	Debrie	TAI	step opt	4 fps	24 fps	80
L	Debrie	Matipo	step cont	4 fps	16 fps	45
A	Union B	TUM	cont cont	no data	no data	no data
A	Debrie	Matipo TC	step cont	4 fps	16 fps	60
A	Debrie	Matipo TC	step cont	4 fps	16 fps	60
A	Debrie	Matipo TC	step cont	4 fps	16 fps	60
A	Debrie	Matipo XU	step cont	4 fps	12 fps	20
A	Debrie	Matipo XU	step cont	4 fps	12 fps	20
A	Debrie	Tipro P18	step opt	no data	no data	no data
A	Debrie	TAI	step opt	5 fps	24 fps	50–90
A	Debrie	TCI 35	cont cont	1000m/hr	3000m/hr	55
A	Debrie	Matipo V	step cont	no data	no data	no data
A	Precino	GMF	step opt	5 fps	25 fps	36
A	Debrie	TAI	step opt	5 fps	25 fps	50–94
A	Own make		step opt	n data	no data	no data
L	Filmtechnik		step opt	2 fps	12 fps	30
L	Debrie	Matipo	step cont	4 fps	16 fps	50
L	Debrie	TAI	step opt	5 fps	24 fps	18–90
L	B&H/Schmitzer	Mod C	rot cont cont	60 fpm	90 fpm	60
L	Debrie	Matipo	step cont	4 fps	16 fps	40
L	Debrie	B&H	Mod C	60 fpm	160 fpm	60
A	Debrie	U?	step cont	4 fps	10 fps	15
L	Debrie	Matipo	step cont	4 fps	16 fps	40
L	Debrie	Matipo	step cont	4 fps	16 fps	40
L	Arri	no data	step opt	no data	no data	no data
L	ex–Cinecitta	no data	step opt	no data	no data	no data
A	Peterson	3190	rot cont cont	60 fpm	180 fpm	60–180
A	B&H	D	cont cont	70 fpm	140 fpm	100
A	Carter	CE–CWP	rot cont cont	no data	no data	no data
A	Carter	CE–CWP	rot cont cont	70 fpm	140 fpm	70
A	Producers Services	Acme104	step opt	2.5 fpm	40 fpm	10
A	Animation Eqipment	Oxberry	step opt	2 fpm	16 fpm	10
A	Oxberry		step opt	4 fpm	16 fpm	20 (35mm)
A	B&H	Mod D	cont cont	10 fpm	40 fpm	20
A	B&H	Mod D	cont cont	10 fpm	40 fpm	20
	B&H	Mod C	rot cont cont	60 fpm	180 fpm	60
A	Sigma		cont opt	30 fpm	60 fpm	30
A	Sigma		cont opt	30 fpm	60 fpm	30
A	Debrie	Matipo	step cont	2 fps	10 fps	Aug–38
A	Debrie	Matipo	step cont	2 fps	10 fps	Aug–38
A	Debrie	Truca	man opt	manual	manual	v. slow
A	Neilson–Hordell	71/84	step opt	1 fps	4 fps	Apr–15
A	B&H	Panel 16	rot cont cont	60 fpm	240 fpm	160
A	Debrie	TCI	rot cont cont	60 fpm	240 fpm	160
A	Oxberry		step opt	4 fpm	16 fpm	15–60?
A	B/H Gaumont	608	cont cont	no data	no data	no data
A	Debrie	Matipo	step cont	4 fps	16 fps	15–60
L	Oxberry		step opt	1 fps	5 fps	15
L	Oxberry		step opt	4 fps	8 fps	15
L	Peterson	Unidirect	rot cont cont	60 fpm	180 fpm	60
A	B&H	Mod C	rot cont cont	60 fpm	180 fpm	60–180
A	Debrie	Matipo TC	step cont	4 fps	20 fps	60
A	Debrie	Matipo X	step cont	1 fps	8 fps	Apr–30
A	Debrie	TOP?	step cont/opt	8 fps	24 fps	30–90
A	Research Products		step opt	data incorr	data incorr	
A	BH–Seiki	1A	step opt	8 fps	48 fp	90
A	B&H	Mod J	cont cont	10 fpm	20 fpm	20
A	B&H	Mod C	rot cont cont	60 fpm	180 fpm	60–180
A	B&H	Mod C	rot cont cont	60 fpm	180 fpm	60–180
A	B&H	DC 35	cont cont	60 fpm	90 fpm	60
A	Depue		step opt	2 fps	15 fps	10
A	Pioneer	7650LP	step opt	1 fpm	300 fpm?	?
L	Peterson	Unidirect	rot cont cont	60 fpm	180 fpm	100
L	B&H	Modular	rot cont cont	60 fpm	240 fpm	100
L	Debrie	Matipo	step cont	4 fps	16 fps	45
L	BHP	Modular	ro cont cont	60 fpm	180 fpm+	60 fps?
L	Oxberry?		step opt	2 fps	8 fps	5 fps
L	BHP	Modular	rot cont cont	60 ft/min	240ftpm	240 ft/min
L	BHP	Modular	rot cont cont	60 ft/min	160 ft/min	160 ft/min
A	BHP	Modular	rot cont cont	60 ft/min	160 ft/min	160 ft/min
A	Debrie	TAI	step opt	5 fps	16 fps	16 fps
A	Debrie	Tipro	step opt	5 fps	16 fps	16 fps

This table includes data from a table published as an addendum to the FIAF Technical Manual together with other data reported to members of the Gamma Group.

Date made	*Register pin?*	*Wet or Dry*	*Gauge*	*Quality*	*Max % shrinkage possible*	*Modifications (as reported)*
no data	no data	W	35/16&16/35	no data	1.50	no data
1990	yes	W	35	fair	1.50	gate modified
1983	no	W	35	good	prob to 2.6	variable pitch as manufactured
1990	no	W	35	no data	prob to 2.6	variable pitch as manufactured
no data	no data	D	35	good	no data	no data
no data	no	W	35	no data	2.0?	variable pitch as manufactured
no data	yes?	D	35	no data	1.50?	no data
1975	no data	D	35	poor	0.06	no data
1965?	no	D	35	fair	1.00	no data
1965?	no	D	35	fair	1.00	no data
1965?	no	D	35	poor	0.80	no data
1955?	no	D	16	fair	1.50	no data
1955?	no	D	16	poor	1.00	no data
1965?	no	D	35–16	fair	1.00	no data
1989	no	W	35	good	2.60	variable pitch as manufactured
1987	no data	W	35	fair	1.07	no data
1930	no	D	35	good	1.47	no data
1970?	no	W	35	good	1.47	no data
1986	no	W	35	good	2.10	variable pitch as manufactured
no data	no data	no data	35	good	no data	no data
1964?	yes	W	35–16&16–35	good	no data	no data
no data	yes	D	35	fair	1.5?	no data
1990?	no	W	35	good	2.50	variable pitch as manufactured
1975/90	yes	W	35	fair	1.50	gate modified
1955?	yes	D	35	good	3.00	no RP/claw filed
1968?	no	D	35	fair	0.80	general wear
1935–40	no	D	35	good	2.40	no data
1950?	yes	D	35	fair	1.80	no data on mod
no data	yes	D	35	fair	no data	no data on mod
no data	no data	D	35–16	no data	no data	no data
no data	no data	W	35–35,16–35	good	no data	no data
1975?	no	D	35	fair	1.00	no data
1915!	yes	D	35	good	2.00	reduced sprockets
1982	yes	W	16	good	2.00	reduced pitch
1984	yes	W	35	good	2.00	reduced pitch
1970	yes	W	35–35	good	3.00	modified gate
1975?	yes	W	35–35	good	3.00	interchangeable gates
no data	yes	W	35/16&16/35	good	3.00	interchangeable wet gates
1935?	no	D	35	fair	2.00	flatbed/worn drive
1935?	no	D	35	fair	2.00	flatbed/worn drive
1975?	no	D	35	poor	0.00	no data
1990	no	W	35	good	5.00	varible pitch and drive standard
1991	no	W	35	good	5.00	varible pitch and drive standard
1955?	yes	D	35	good	5.00	no RP
1965?	yes	D	35	good	5.00	no RP
1936		D	35	good	5.0++	manual pulldown, sprocketless
1981	no	W	35	good	2.50	no data
1975?	no	D	16	no data	no data	probably not for shrunken film
1988	no	D	35	no data	no data	probably not for shrunken film
no data	no	W	35/16&16/35	no data	no data	no data
1946	yes	D	35ST only	fair	1.00	modified gate
1956	yes	D	35	good	3.10	short RP/worn claw
1945?	yes	D	35	fair	0.80	mod gates/for separations
1966?	yes	W	35	good	3.00	interchangeable gates
1983?	no	W	35	fair	0.50	film waxed
1975	no	D	35	no data	no data	probably not for shrunken film
1976	no	D	35	no data	no data	no data
1936	yes	D	16	no data	no data	no data
1970	no	D	35–16 16–16	no data	no data	no data
1976	no	D	35/16&16/35	no data	no data	no data
1976	no	W	16/35–16/35/8	no data	no data	no data
1932	no	D	35	fair	no data	no data
no data	no	D	35	fair	1.30	no data
no data	no	D	35	fair	1.30	no data
no data	no	D	35	fair	no data	no data
1932	yes	D	35–16	fair	3.50	reduced pitch
1982	no	W	35	fair	2.50	no data
1986?	yes	W	35	good	1.80	modified gate
1988	no	W	35	fair	0.80	film waxed
1955?	yes	D	35	good	1.50	regiser pins filed down
no data	no	W	35 &16	fair	1.10	adjusts gate tension for shrunk film
no data	no data	W	35 &16	good	1.80	no data
1994	no data	W	35 &16	good	1.00	none
1996	no data	D	35 &16	fair	1.00	none
1992?	no data	W	35	good	1.00	none
1985	no data	W	35	good	3.00	variable pitch as manufactured
1974	no data	W	16	good	2.50	modified pulldown mechanism

Abbreviations: A, archive; L, laboratory; B&H, Bell & Howell; rot, rotary; cont, contact; opt, optical; W, wet; D, dry; fpm, frames per minute; fps, frames per second; ft/min, feet per minute.

28

Production of a grader training aid

28.1 PRODUCTION OF THE AID

Step 1 A length of Eastman Colour Negative is loaded into a conventional 35 mm still cassette and exposed in a 35 mm still camera, frame by frame using conventional filters and speed indices as recommended for the product.

Step 2 The length is processed normally and spliced into a loop sufficient for a Bell & Howell Additive Printer.

Step 3 The negatives are printed by conventional trial and error methods (or using a video analyser) until most frames are near correct. The variation from one frame to another is not much more than four to six printer lights in both colour and density if the negative has been exposed with rigorous interpretation of exposure requirements.

Step 4 The program tape is then punched in which the final R, G and B light values are adjusted as set out in section 28.3 below.

Step 5 These prints are then produced.

Step 6 91 frames from one negative are mounted in 2×2 inch card or glass mounts and placed in sequence in a 35 mm still projector magazine which

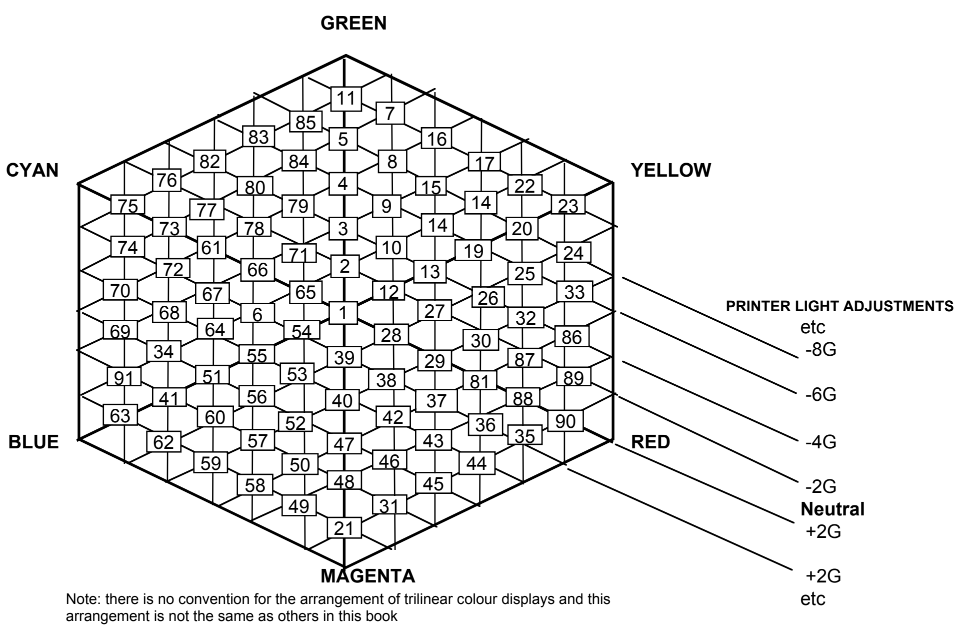

Figure 28.1 Off balance prints of a 91 print ring-around on a trilinear display

has numbers for each slide position, for example a Carousel. The numbers on the magazine should correspond to the numbers of the prints in the table. (No. 92 is a second 'normal' as a check of printer and process stability and should be identical with No. 1.)

Step 7 Many projectors will not take all 91 prints and so some may have to be omitted. It is best to omit some of the extremely off balance prints.

28.2 TRAINING PROCEDURE

28.2.1 Student method

Step 1 The instructor projects a single print on a still projector, which can be any of the 91 prints available, but is usually one of the furthest out.

Step 2 The student makes an assessment of the correction and informs the instructor.

Step 3 The instructor uses the trilinear display to find the print with the student's correction and projects this.

Step 4 The student accepts this print as correct, or makes a further correction as necessary.

Step 5 Once the student is familiar with the system, he or she may take the place of the instructor as the projector operator.

28.2.2 Example

Step 1 Print No. 89 is projected on the screen.

Step 2 The student assesses the print as to R and decides on a correction of +8 printer lights red to correct this.

Step 3 The instructor finds the corrected print by moving from No. 89 four places in the +R or Cyan balance direction (each jump represents two printer light changes). Thus he projects No. 12.

Step 4 The student is still not happy with this and decides that now it is to Y. The student decides on a –4B correction.

Step 5 The instructor now projects No. 54 (two spaces in the –B direction from No. 12).

Step 6 The student decides this is acceptable.

28.2.3 Notes

1. The initial choice of a good average balance at stage 3 of the production should be done by projection with the projector to be finally used.
2. No. 1 or 92 does not have to be a perfect print since personal choice will cause the finally accepted print to vary.

   No. 1 should, however, be within two printer lights of most graders' preference.
3. If two projectors are used with two subjects, a scene-to-scene balance can be achieved by printing the first one, leaving this projected and matching the second to it; projecting the two images side by side.
4. As experience is acquired, a starting position can be used nearer to the centre.
5. It has been found that this method maintains a high sense of involvement and can shorten the time required to gain experience in grading. Obviously, the larger the number of subjects available, the better, but each subject should be done at least twice, starting from different balances.

28.3 THE 91 PRINT RING-AROUND

Print no.	Printer settings R	G	B	Visual balance
1				N
2		–2		2G
3		–4		4G
4		–6		6G
5		–8		8G
6	+2		–2	2B 2C
7		–8	+2	8G 2Y
8		–6	+2	6G 2Y
9		–4	+2	4G 2Y
10		–2	+2	2G 2Y
11		–10		10G
12			+2	2Y
13			+4	4Y
14		–2	+4	2G 4Y
15		–4	+4	4G 4Y
16		–6	+4	6G 4Y
17		–4	+6	4G 6Y
18		–2	+6	2G 6Y
19			+6	6Y
20			+8	8Y
21		+10		10M
22		–2	+8	2G 8Y
23			+10	10Y
24	–2		+8	8Y 2R
25	–2		+6	6Y
26	–2		+4	4Y 2R
27	–2		+2	2Y 2R
28	–2			2R
29	–4			4R
30	–4		+2	2Y 4R
31	–2	+8		8M 2R
32	–4		+4	4Y 4R
33	–4		+6	6Y 4R
34	+2		–6	6B 2C
35	–8	+2		8R 2M
36	–6	+2		6R 2M
37	–4	+2		4R 2M
38	–2	+2		2R 2M
39	0	+2		2M
40		+4		4M
41			–8	8B
42	–2	+4		2R 4M
43	–4	+4		4R 4M
44	–6	+4		6R 4M
45	–4	+6		4R 6M
46	–2	+6		2R 6M
47		+6		6M
48		+8		8M
49		+8	–2	8M 2B
50		+6	–2	6M 2B
51			–6	6B
52		+4	–2	4M 2B
53		+2	–2	2M 2B
54			–2	2B
55			–4	4B
56		+2	–4	2M 4B
57		+4	–4	4M 4B
58		+6	–4	4M 4B
59		+4	–6	4M 6B
60		+2	–6	2M 6B
61	+6			6C
62		+2	–8	8B 2M
63			–10	10B
64	+2		–4	4B 2C
65	+2			2C
66	+4			4C
67	+4		–2	4C 2B
68	+4		–4	4C 4B
69	+4		–6	4C 6B
70	+6		–4	6C 4B
71	+2	–2		2C 2G
72	+6		–2	6C 2B
73	+8			8C
74	+8		–2	8C 2B
75	+10			10C
76	+8	–2		8C 2G
77	+6	–2		6C 2G
78	+4	–2		4C 2G
79	+2	–4		2C 4G
80	+4	–4		4C 4G
81	–6			6R
82	+6	–4		6C 4G
83	+4	–6		4C 6G
84	+2	–6		2C 6G
85	+2	–8		2C 8G
86	–6		+4	4Y 6R
87	–6		+2	2Y 6R
88	–8			8R
89	–8		+2	8R 2Y
90	–10			10R
91	+2		–8	8B 2C
92				N

28.4 AN ALTERNATIVE 37 PRINT RING-AROUND

Print no.	Printer settings R	G	B	Visual balance	
1	–2			2R	
2	+2	–2		2G	2C
3		+2	–4	4B	2M
4	–2		+2	2R	2Y
5	+4		–2	4C	2B
6		–2	+4	4Y	2G
7	–2	+4		4M	2R
8		–2		2G	
9		–6		6G	
10	–6			6R	
11	+2			2C	
12		+2		2M	
13	+4	–2		4C	2G
14			+4	4Y	
15			–4	4B	
16	–2	+2		2R	2M
17			–6	6B	
18		–4	+2	4G	2Y
19			+2	2Y	
20		+6		6M	
21	+2		–2	2B	2C
22	–4			4R	
23				N	
24	–2		+4	4Y	2R
25	+4			4C	
26	–4	+2		4R	2M
27		+2	–2	2B	2M
28		–4		4G	
29	+2		–4	4B	2C
30		+4		4M	
31	+6			6C	
32	–4		+2	4R	2Y
33	+2	–4		4G	2C
34			–2	2B	
35		+4	–2	4M	2B
36			+6	6Y	
37		–2	+2	2G	2Y
N				N	

28.5 ALTERNATIVE 37 PRINT RING-AROUND

Use the following numbers only on the 91 ring-around:

1	N	40	14	N	61
2		42	19		64
3		47	26		65
4		51	27		66
6		52	28		67
9		53	29		71
10		54	30		78
12		55	37		79
13		56	38		81

29

Black and white duplication methods

29.1 TWO-POINT METHOD FOR THE PRODUCTION OF A BLACK AND WHITE DUPLICATE NEGATIVE

29.1.1 Making the black and white interpositive (master positive)

Step 1 Plot on graph paper the characteristic curve of the interpositive material to be used. This will probably be either Eastman Fine Grain Duplicating Positive film or Eastman Panchromatic Separation film (see the printing route diagram in Chapter 8). The contrast (gamma) at which the film will be processed will be selected from a time–gamma curve previously prepared, probably 1.5, to fit the pre-selected contrast of the duplicate negative film.

Step 2 Find a suitable test negative with a series of plain uniform areas large enough to measure on the available densitometer, preferably using a 3 mm aperture. This test negative could be a locally shot scene including a grey scale, a Kodak LAD negative, a BKSTS or an SMPTE standard negative, or a process control strip. It should be on a similar material to the originals to be duplicated. If the original is a conventional black and white, a black and white negative is used. Mark on the control strip or test negative the steps that correspond to the **highest** and the **lowest** densities you can read **off the original work negatives.**

Step 3 Print the standard negative or control strip at a range of exposures on the printer to be used to make the interpositive.

Step 4 Process the test printing to achieve the pre-selected gamma.

Step 5 Measure the 'print-through' densities on the interpositive and plot them onto the characteristic curve produced in Step 1 above.

Step 6 Assess which exposure of the test negative falls entirely within the straight-line portion of the characteristic curve, and if none does make a new set of exposures in order to place the full range of 'print-through' densities on the straight line. If the lowest density step is on the curved toe then a higher exposure is needed, if the highest step is on the shoulder a lower exposure is needed. Continue to test until the range falls on the straight line.

Step 7 Expose the work at the defined exposure. Some black and white interpositives are made using the grading exposures used in printing the original negative and result in a 'graded interpositive' or 'graded master' which, when printed to make a duplicate negative, can be printed at one printer light to achieve the original grading. This may not be practical with archive film.

29.1.2 Making the duplicate negative

Step 1 Plot on graph paper the characteristic curve of the duplicate negative material to be used. This will probably be Eastman Fine Grain Panchromatic Duplication Negative film (see the printing route diagram in Chapter 8). The contrast (gamma) at which the film will be processed will be selected from a time–gamma curve previously prepared, probably 0.65–0.70, to fit the pre-selected contrast of the duplicate negative film.

Step 2 Find a suitable test interpositive with a series of plain uniform areas large enough to measure on the available densitometer, preferably using a 3 mm aperture. This test image could be the interpositive made above as the test for preparing interpositives, or a process control strip on the interpositive material. Mark on the control strip or test negative the steps that correspond to the **highest** and the **lowest** densities you can read **off the original work interpositive.**

Step 3 Print the standard interpositive or control strip at a range of exposures on the printer to be used to make the duplicate negative.

Step 4 Process the test printing to achieve the pre-selected gamma.

Step 5 Measure the 'print-through' densities on the duplicate negative and plot them onto the characteristic curve produced in Step 1 above.

Step 6 Assess which exposure of the test film falls entirely within the straight-line portion of the characteristic curve, and if none does make a new set of exposures in order to place the full range of 'print-through' densities on the straight line. Make corrections as described above.

Step 7 Expose the work at the defined exposure to make the final duplicate negative.

Note: The resulting duplicate negative will need grading much as the original negative would have needed unless the interpositive was made with grading correction. Even if this is the case it is unlikely that an entire production will only need one printer light setting.

29.2 LAD METHOD FOR BLACK AND WHITE DUPLICATE NEGATIVE PRODUCTION

Kodak has published values to enable the LAD method to be used on some black and white film stocks. The method used should be a form of the methods described in Chapter 14 on Grading, but measuring of the LAD step to Status V density.

Original B/W negative (Kodak stocks)	0.65
Eastman Fine Grain Duplicating Positive film	0.75
Eastman Fine Grain Duplicating Panchromatic Negative film	0.75

29.3 TWO-POINT METHOD FOR THE PRODUCTION OF A BLACK AND WHITE INTERNEGATIVE FROM A POSITIVE

Step 1 Plot on graph paper the characteristic curve of the internegative material to be used. This will probably be Eastman Fine Grain Duplicating Panchromatic Negative film, whether the original is a black and white, or colour, a reversal original, a tinted, toned or stencilled print (see the printing route diagram in Chapter 8). The contrast (gamma) at which the film will be processed will be selected from a time–gamma curve previously prepared, probably from 0.45–0.60. The gamma required will probably be found by experiment and the following is only a guide:

Black and white release prints	0.40–0.65
Black and white reversal originals	0.40–0.50
Tinted and toned films for Desmetcolor	0.45–0.50
Tinted and toned films for black and white prints	0.55–0.60
Colour prints – neg /pos	0.50–0.55
Colour prints – Technicolor	0.40–0.45
Kodachrome and early colour reversal	0.35–0.45
Reversal colour news film	0.50–0.55

Step 2 Find a suitable test with a series of plain uniform areas large enough to measure on the available densitometer, preferably using a 3 mm aperture. This test image could be a locally shot scene including a grey scale, a Kodak LAD print, a BKSTS or

an SMPTE standard print, or a process control strip. It should be on a similar material to the originals to be duplicated. If the original is a conventional black and white, a black and white print is used. Mark on the control strip or test print the steps that correspond to the **highest** and the **lowest** densities you can read **off the original work negatives.**

Step 3 Print the standard image or control strip at a range of exposures on the printer to be used to make the internegative.

Step 4 Process the test printing to achieve the pre-selected gamma.

Step 5 Measure the 'print-through' densities on the internegative and plot them onto the characteristic curve produced in Step 1 above.

Step 6 Assess which exposure of the test negative falls entirely within the straight-line portion of the characteristic curve, and if none does make a new set of exposures in order to place the full range of 'print-through' densities on the straight line. If the lowest density step is on the curved toe then a higher exposure is needed, if the highest step is on the shoulder a lower exposure is needed. Continue to test until the range falls on the straight line.

Step 7 Expose the work at the defined exposure.

Note: Some internegatives are made using grading changes to printer lights judged to correct the original print (by sight grading), and the resulting internegative carries the corrections and can be printed at one printer light throughout. This may not be practical with archive film, but does reduce the effort of grading later.

29.4 LAD METHOD FOR BLACK AND WHITE INTERNEGATIVE PRODUCTION

The Kodak published values to enable the LAD method to be used on some black and white film stocks can also be used to set values for a black and white internegative. The method used should be a form of the methods described in Chapter 14, but measuring of the LAD step to Status V density.

Eastman Fine Grain Duplicating Panchromatic Negative film	0.75

30

Flashing techniques for film

30.1 INTRODUCTION

Flashing enables technicians to devise their own contrast control rather than be restricted to the particular set of conditions for which the manufacturer designed the film. It is inevitable that stocks used for duplication alter in specification from time to time, and are replaced by new films. Manufacturers of duplicating films do not devise them for archive use and a film archive technician must be familiar methods of adapting films for non-standard purposes.

Pre-flashing is generally more effective in reducing contrast than post-flashing, which is often unpredictable and may only increase density rather than effect contrast.

30.2 SETTING UP A PRE-FLASHING SYTEM

In order to estimate the degree of pre-flashing needed for a duplication procedure, prepare a pre-flash exposure series as follows:

Step 1 Expose a number of film strips of the duplication material or print stock in a sensitometer to a wedge in the usual exposure conditions to produce a conventional characteristic curve.

Step 2 Process one strip conventionally without any pre-flashing and plot the curve.

Step 3 Expose the remainder in a continuous rotary contact printer, for example a Bell and Howell Model C, to a series of neutral density filters placed in the filter holder in the light beam – a range of 1.00, 2.00, 3.00 is suggested to start. Use a trim setting suggested by the normal LAD set-up system for this stock as a starting point. Process the strips in the same standard process and plot the characteristic curves.

Step 4 A comparison of the curves will show the degree of contrast reduction achieved by each exposure level. (**Note:** If the film stock is colour and if the three curves are no longer parallel to each other the colour of the exposing light may be adjusted to compensate. This can be done by using subtractive filters but is more easily achieved by adjusting the trim settings of an additive printer lamphouse. As a guide for negative–positive duplication:

- Red contrast lower than rest: lower the red exposure – reduce the red trim value.
- Green contrast lower than rest: lower the green exposure – reduce the green trim value.
- Blue contrast lower than rest: lower the blue exposure – reduce the blue trim value.
- If the duplication process is copying onto a reversal film the trim values shown above are increased, not reduced.)

Step 5 Colour films only: repeat the series until the curves are parallel. Some stocks do not behave uniformly when pre-flashed and colour negative films and negative type duplicating films are easier to set up than reversal films.

Step 6 Use the estimated trim values for all pre-flashed material. All pre-flashing can be done on just one printer, regardless of the printer to be used for the image. Always use a continuous printer with full frame gate (or the Academy gate removed), which produces a uniform flash over a band between the perforations. This pre-flashed stock can then be used on any other printer – step or continuous.

Step 7 The degree of flashing needed for any particular restoration is almost impossible to estimate without making a test. Different batches of film of the same emulsion type seem to behave differently.

31

Original tinting and toning techniques and their adaptation for the restoration of archive film

31.1 INTRODUCTION

The images produced by using the original tinting and toning recipes are closer to the originals in their pristine condition than any reproduction on modern colour film. The process is very time-consuming and probably not as economic as the Desmet process for large quantities of restoration.

Tinting is the process of colouring the silver print image overall with a dye in the emulsion or the film base or by applying a coloured 'lacquer'. Stencilling and hand colouring was the process of locally applying tint dyes to the silver image. Toning is the process of replacing the silver image with a coloured image material.

We have only seen reference to the lacquering process mentioned above in the Agfa technical process manual of about 1925 and in a list of dyes from a French dye manufacturer described as suitable for this process. This indicates the use of 'lac' dyes in a varnish-like solvent applied over the picture area between the perforations to create a tint. (Lac was a varnish made from the secretion of an insect in India.) This coloured stripe would be very easy to identify, but we have never seen an example nor did the Nederlands Filmmuseum survey of their own collection reveal any.

Hand coloured and stencilled films were produced by locally colouring a black and white positive print. Some of the prints were presumably made slightly light in density but the techniques and the dyes used to dye the film were the same as for tinting, except for the local application. A number of stencilled films were made on tinted film base or seem to have been tinted overall as well, usually pale yellow.

31.1.1 Technology of coloured nitrate film

By the time cinema commenced in 1896, photography was many decades old and a wide range of techniques for colouring the neutral silver images had been tried out on paper prints, and more importantly for cine film, on glass lantern slides.

Some of the earliest experiments used natural dyes such as logwood (reddish brown), madder (red), indigo (blue) and turmeric (yellow) to dye gelatine, paper or the silver images. By the time cinematography existed a number of proven, ready made, techniques using synthetic dyes already existed. There is surprisingly little early technical literature on the methods used to colour film and although it seems likely that handcolouring and stencils came before overall tinting and toning, which was a cheaper alternative, tinting lantern slides was described in several still manuals of the 1880s.

31.1.2 Metallic toning

Image silver is neutral in colour and all its salts are white or more or less neutral to transmitted light. However, the silver of the image can be replaced by other metal salts. If these salts are coloured, insoluble and relatively transparent (generally in the form of a colloid) the neutral image can be replaced by a coloured one.

Toning processes using metal ferrocyanides were known to photographers well before motion pictures. The Iron Tone Blue or Iron Blue process was known as Cyanotype to photograhers and used on paper from the 1860s. Several techniques used on paper are unsatisfactory on film as the resulting dye is not transparent and is seen as black when projected (although it may be highly coloured by reflected light, e.g. sulphide, selenium and gold toning).

The following metal salts were widely mentioned for metallic toning cine film:

Ferric ferrocyanide (Prussian Blue)
  blue, blue–green or olive green
Uranium ferrocyanide
  orange–red, red or red–brown
Copper ferrocyanide
  red or reddish brown
Vanadium ferrocyanide
  yellow, yellow–brown, or olive green
Silver sulphide
  blue–black to brown (the traditional reddish brown of still photographs is only produced from very 'thin' images, as sulphides are opaque)

Sepia, as seen on old paper prints, is silver sulphide, and is red-brown by reflected light. This colour was desirable on cinema film but silver sulphide is almost completely opaque and therefore projects as a neutral or blue–black image. The most usually mentioned 'sepia' colour was achieved by creating a mixture of ferric and uranium ferrocyanides, and an olive green was produced by mixing vanadium and uranium ferrocyanides).

The process usually comprised a single toning bath of potassium ferricyanide (the silver bleach) and a metal salt. 'Fixing' if it was done was a separate solution, probably a conventional black and white fix bath, sodium thiosulphate (see below). The chemistry of these reactions was not well known until the 1930s, well after toning ceased to be important in this respect. Many of the early toning procedures were more akin to cookery than chemistry!

(In the 1920s and 1930s a lot of research and development went into Prussian Blue and uranium ferrocyanide toning in order to produce 'perfect' two-colour primaries that were complementary, for use in the various duplitized positive two-colour films such as Cinecolor, Trucolor, Dascolour etc.)

By the mid-1920s it is possible that the only widely used metallic tone was Iron Blue (Prussian Blue). Uranium was expensive and toxic, copper recipes often damaged the film emulsion, vanadium was only available as a messy concentrated impure 'syrup', and all were a little unpredictable. Several papers, as early as Reid 1917, indicate that mordant dye toning could do everything metallic toning could do but better. However, Iron Blue certainly continued, probably as it produced such an unique amazing blue colour. Apparently there were no strong blue mordant dyes at that time.

Several papers and 'recipe books' indicate that the residual salts in the image, usually white silver ferricyanide and/or metallic silver could be removed by 'fixing' or 'clearing', using an acid sodium thiosuphate solution (a fixing bath). The chemical process here is a little uncertain, but the result is a bright clear translucent image of high saturation. This image is recognizable from the pristine unprojected sample books from Gevaert and Pathé. (Prussian Blue fades in the projector – sometimes almost the entire image vanishes except at the frame corners – and it also ages by darkening and becoming desaturated, more neutral.)

31.1.3 Synthetic dyes for tinting

The earliest photographic processes existed before the discovery (by mistake) of the first artificial dye (Mauveine) by Perkin in England in 1856. By 1896, man-made dyes were being discovered (or invented) at a tremendous rate. The early development was in England, later Germany, France and then the USA developed considerable numbers, and by 1910 the USA was the largest producer. These dyes originated from complex organic chemicals in coal, oil and tars and were not of just a single type. No doubt hundreds were tested on film (about 5500 dye chemicals of this type are known today), but many were quite unsuitable. Some dyes are inflammable, explosive or toxic, and some of the intermediate chemicals are equally dangerous (Perkin blew up two factories during his lifetime!). Others were found to cause rapid and permanent damage to film emulsions, resulting in the first use of the term 'brittleness' in photography (the emulsion cracked and peeled off the base). Frothing of the dye solution also seems to have been a common problem.

By about 1920 Eastman, Gevaert and Pathé were recommending specific dyes, but presumably some very unsuitable ones had been in use at earlier times. Most dyes were selected for their solubility in water, and many were originally used in dyeing wool, like gelatine, a protein. Most of the most suitable dyes have stood the test of time and are still available today.

All dyes fade (either decolorize, darken or change hue) in time and in certain conditions of temperature, humidity and UV irradiation, but surprisingly little information exists as to which dyes fade in which way, creating a major problem for those of us who wish to identify and re-use the original dyes for restoration.

These synthetic dyes useful in photography fall into two broad categories, 'acid dyes' generally available as a sodium salt which are mostly used for tinting (and 'basic dyes' that can be mordanted to the substrate are used for mordant dye toning: see below).

A typical tinting process consisted of soaking the black and white print film in an aqueous solution of dye (from 0.5–20 g per litre) acidified with acetic acid. The film was then washed in water to remove excess dye.

Many of the English and American papers refer to 'Cine' Red, Green, Light Green, Blue and so on. This loose term presumably originated with Eastman Kodak, but other authors use the same terms often referring to other dyes.

31.1.4 Mordant dye toning

A mordant is a chemical to which a dye bonds, loosely or intimately, and if the mordant is in the emulsion in the form of an image, a dye image is produced. Photograhic silver is not a mordant for dyes, but some of the salts of silver are; likewise some related metal salts are mordants and can replace the silver. The most used mordants were:

- silver iodide
- silver ferricyanide, and silver ferrocyanide
- uranium ferrocyanide
- copper ferrocyanide.

Generally the mordants were retained in the film emulsion and some, like silver ferricyanide, were relatively translucent. In some processes the mordant was subsequently removed (by a 'clearing bath') to leave a 'bright' or transparent highly saturated image, analogous to the 'fixing' of Iron Blue. Some of the frames in the Gevaert and Pathé sample books we have seen, presumably that have never been projected, are dazzling and highly saturated.

A typical two-stage mordant dye process consisted of a solution of 'mordant bleach', usually acid potassium ferricyanide, with or without a halide, or another metal salt, to produce one of the mordants above as a replacement for the silver image, followed by an aqueous solution of a 'basic' dye (usually about 1–5 g per litre).

Following the toning bath, the film is washed to remove the excess toning dye from the emulsion. The length of this wash (and the temperature and pH of the wash water), can be critical, as the toning dye can be removed or reduced by a long wash. Similarly we have identified toned images with dye retained in non-image areas (like a tint of the same colour, easily achieved by reducing this wash time).

A 'clearing' stage to remove the mordant is usually a conventional photographic fixer of sodium thiosulphate applied after the wash and followed by a further wash stage.

31.2 THE ORIGINAL LABORATORY TECHNIQUES

31.2.1 Processing

Most of the American laboratories from the earliest times until about 1920 carried out their conventional processing in batches of 200 ft of film wound round wooden cylinders called 'drums' that just dipped in shallow trays of processing solution and were continuously rotated. Batch processing continued, at least in America, until about 1929. Drums, flat wooden 'racks' holding 200 ft, submerged in deep tanks, and 'pin racks', in which the film is wound in a concentric spiral, continued to be used. Presumably the same or similar equipment was used for both development and for tinting and toning.

Both Pathé and Gaumont experimented with 'tube' processors, some of which were continuous and these may have been used for tinting and toning. Continuous processors are mentioned in early patents and some literature, but it is difficult to be certain where and when these were first used extensively.

31.2.2 Positive cutting or 'Assembly'

Until about 1930 it is believed that many, or most, films were finally assembled as positives. In colloquial laboratory parlance they were 'pos cut' and not cut as negatives, or 'neg cut'. In effect, short single scenes were made up into small rolls which were then printed in one printer pass for each roll onto lengths of print stock. The resulting short lengths of print were then 'pos cut' to make the final print. Multiple copies were made by multiple positive cutting. Today, this would seem incredible and although literature of the time occasionally describes this, it is sometimes difficult for a modern film technician to accept.

Certainly not all films were treated this way and the British Pathé collection, just as an example, contains newsreels and magazine programmes, like *Eve's Fim Review* (1918–1928 approx.), in which each short story was a series of joined negatives, just like a modern cut negative. Presumably these programmes were never intended to be coloured. Some films (e.g. *Blood and Sand* and *Cabiria*) were released with the same colour effect throughout, so these could have been 'neg cut', but few processors could process continuously until the 1930s. Undoubtedly almost all tinted and *all* toned material was 'pos cut'.

An interesting example which was not entirely 'pos cut' is a section of 'Bachanale' (1916?) in the Nederlands Filmmuseum which has several 'fast cut' tinted sections where the colour changes at intervals throughout a scene. The colour sections are short and might correspond to a segment of a film rack about 40 cm or so in diameter. Different segments were dipped in different tinting solutions.

31.2.3 Pre-tinted film base

All tinted film was made by dipping the finished print into an aqueous solution of dye (sometimes called 'post-tinting'), until about 1918, when 'pre-tinted' base became available.

Pre-tinted film was sold until about 1930, and it might be expected that pre-tinted film very quickly replaced 'post-tinting', However, an American laboratory textbook of 1927 and a French manual of 1926 both imply that laboratories at that time still tinted much of their own prints as a routine.

Pre-tinted base is more uniform than 'post-tinting', although not universally, and can be separated from post-tinting by scratching the emulsion off in an area outside the frame. If the film is pre-tinted, i.e the base material dyed, or a layer of tinted material on the back of the film, the colour will not change. If the film is post-tinted the clear base shows through the scratch. As an example, *The Pleasure Garden* (1925) is tinted throughout with nine colours. Probably two are pre-tints and six are post-tints. One strong blue tint dye exists as both pre-tint and post-tint (probably Patent Blue), as if the laboratory ran out of pre-tinted base during production! The 'reel number' leaders and the 'end of reel number' tails are also also tinted.

In the catalogue of the chemical supply company Société Anonyme des Matières Colorant & Produits Chimiques de St Denis, France, apart from a list of dyes for tinting gelatine, there is also a list of dyes suitable for dyeing cellulose nitrate film base.

The paper by Lloyd Jones on the Eastman Kodak product Sonochrome lists all the 17 pre-tinted bases available in 1929 for printing sound prints. Some of the previous tint dyes had significant densities in the infrared and reduced the signal to noise ratio of optical sound tracks.

31.2.4 Toning

Toning was *always* done in the laboratory and was also difficult to do in long lengths. Positive cutting must have been used for *all* toned material, as toning by the usual techniques can only be done after the print is made. Toning is often quite a fast chemical reaction and agitation was essential to achieve even results. We have found that the Iron Blue process is particularly critical.

A further complexity of Iron Blue was that the full colour could take some hours to develop, well after the film was dry and rolled up! This has made modern process control a problem as we now have to wait six hours before establishing whether the process was on aim!

31.2.5 Double effects

Double effects, such as the common Iron Blue tone and pink or yellow tint, would be most conveniently produced by using pre-tinted base film and toning the print, but most Iron Tone Blue and pink or yellow tint we have seen have both been produced in the laboratory.

The Lodger (1927), uses Iron Tone Blue and amber tint for all the exterior scenes to produce a double effect that simulates a London ‘particular’ (a smog), in which the amber tint varies considerably in depth from scene to scene. Some film is pre-tinted, and some post-tinted, in both cases on Kodak film. The intertitles are on a different stock, Pathé, probably negative or ‘process’ film, and these were all tinted in the laboratory to a denser and more orange colour.

31.3 ADAPTATION TO THE MODERN LABORATORY

Hand coloured and stencilled prints have generally been preserved on colour internegative, but much of the tinted and toned material has not been preserved in colour. Most early coloured film is preserved in archives as black and white duplicate negatives and prints with just a written record of the colours. The image has good archival permanence but there is no visual record of the colours, either as faded by time, or as originally seen. Most archives carry out some colour reproductions for display purposes but all are prints on modern colour print stocks. The Nederlands Filmmusem has copied large amounts of coloured film using Eastman Colour Internegative film, and the Cinémathèque Royale de Belgique has used the Desmetcolor method for many years.

The Lodger was restored by tinting and toning by Harold Brown at the National Film and Television Archive in 1984, and this was also the first film Soho Images restored by this technique.

31.3.1 Tinting and toning a modern black and white print

If the dyes and chemistry are the same as originally used in the first three decades of this century the results should be closer to the original than any other method:

Original coloured image
↓
Panchromatic B/W negative
↓
B/W print

or

Any duplicate negative
↓
B/W print

The final B/W print is then tinted or toned using original chemistry.

31.3.2 Fading

When the original dye has faded it may be difficult to define original hue and saturation. Tone dyes are the image, and when these fade the image will be destroyed too, where there is no retained silver. This is particularly true of the metallic tones, especially the various green and blue iron tones, which darken and desaturate. Any negative made from a faded tone will show a loss of detail and may become almost ‘posterized’, giving the effect of a reduction in tonal range to just a few flat tones. The resulting negative will carry only the detail left in the print.

31.3.3 Decay

Some tone effects ‘decay’ in a manner that creates a locally reversed (sometimes erroneously called solarized) image, in which the high densities lose more density than low densities. Commonly associated with this is an irridescence on the image surface, which seems to be a redistribution of the remaining metallic silver. It has been considered that these reversal effects could have been intentional. In our experiments we found that some formulae for producing green metallic tones were prone to this effect, but that it was almost impossible to control. We are of the opinion that the effect was never intended, may have been retained from sense of serendipity, and some may well date from the original print production, although we cannot be sure.

We do not know a method of preparing a conventional image from a partially reversed print such as this other than by digital restoration.

31.3.4 'Laking'

Many tint dyes, especially those that seem to have been used at high concentrations, appear to have 'precipitated' or 'laked' in the print emulsion to create a cloudy overall effect, that does not effect the making of a good negative but that reduces the overall brightness and contrast of the original print. Any reproduction on a clear base print film will restore this transparency, presumably to that approaching the original image.

31.3.5 Using modern subtractive primaries

It was realized that because some of the techniques were difficult (or just messy!) many previous experimenters had departed from the original formulae and had substituted modern alternatives. One technique tried in the UK and in the USA (private correspondence) had been to use the Technicolor imbibition dyes, cyan, magenta and yellow, and mix them to match the colour of tinted film. Subtractive mixing of dyes cannot achieve the saturations of some single bright dyes.

31.3.6 Positive cutting

Most experimenters had rejected the entire concept of using the original techniques because it was felt that positive cutting resulted in an increased risk of break in projection.

31.4 SOURCES OF TECHNICAL DATA ON DYES

- The early *Transactions of the Society of Motion Picture Engineers* in the USA.
- The publications of the main film manufacturers, Eastman Kodak, and Pathé, demonstration sheets of Gevaert and Agfa, and there are a few 1920s books on film laboratory practice, see Bibliography.
- Catalogues and databases produced by modern manufacturers or factors of dye chemicals.
- Catalogues from dye suppliers of the period.
- Literature, registers and the Colour Index of the Society of Dyers and Colourists, Bradford, England.
- Industrial chemistry and engineering journals of the period.

At first sight the film manufacturers' books and data sheets would seem to be the best source, but these contain very little practical information. Literature earlier than 1920 is rare and there is therefore little about the dyes used prior to this period. The practical data is often contradictory or just anecdotal, and it was clear that the laboratories must have developed their own local approaches and acquired techniques that may never have been written down, until a few manufacturers' published recommended dyes and recipes.

31.5 IDENTIFYING THE PROCESS AND DYE

Ideally the objective should be:

- to identify the process and if possible the original dye or dyes used;
- to use modern film but the original process and if possible the original dye to prepare the restoration.

Status A densitometry and trilinear plots can demonstrate whether trials are successful in producing visual matches. This technique is used in the *Quo Vadis* case study.

Some dyes, Iron Blue, Amaranth, Rhodamine B for example., are unmistakable. Others, especially the plethora of yellows, ambers and oranges, are a minefield. Surprisingly, however, many of the original dyes are available today, some under synonyms. Acetate- and Estar-based film seem to behave identically, but Agfa print film (now not available) required higher tint dye concentrations than Eastman 5302 to produce the same effect.

31.6 SYNONYMS AND MODERN DYES

A primary source of data is the Colour Index, a register of worldwide dyes and dye manufacturers, produced by the Society of Dyers and Colourists of Bradford, UK. The first Index was 1926 and all the dyes described in the literature listed in our references are shown with the registering company, the manufacturer. However, such information is not always useful, since many dyes exist in different forms, fabricated in different ways to slightly differing 'recipes'. Since synthetic dyes are rarely purer than 80%, the rest being the originating chemicals, or their impurities, the colours vary a little. Croceine or Direct Blue are single unique chemical structures but exist in numerous formulations of purity and additional dye content. Furthermore, nothing prevents a manufacturer registering a name of his own, and this process of renaming has been going on for 100 years or more.

These problems have beset the dyeing industry for generations, and dye manufacturers and factors have generated databases to find synonyms. (Dye chemists do not like using the term synonym because the different names do correspond to slightly different products that include the same basic dye chemical.)

Nevertheless, the best method of locating a dye is to ask a manufacturer to look for the name in his synomym list. This may find the original dye under its modern name. One dye regularly used for blue tinting in the 1920s was Direct Blue and this exists in one database with 84 different 'synonyms' including Chicago Sky Blue, the name under which the dye can be purchased today.

31.7 DUPLICATE NEGATIVE AND PRINT PRODUCTION

If an existing print on Estar (see below) is not available there is a choice as to which route a laboratory should take to reach the positive cutting procedure.

1. A duplicate negative made from an original is made overlength at the colour changes by 'pulling back' the nitrate original print in the printer to acheive a few frames extra. The advantage of this method is that the duplicate negative produced is in one length and can be printed on a production rotary contact printer in one pass. The disadvantage is the risk of damage to the original during the 'pulling back'.
2. A duplicate negative is made in one pass and then printed with 'pull backs' during the print production process. This makes the initial duplicate negative printing easier, especially if it is wet gate. It slows down the final printing.
3. A duplicate made in one pass can be used to make two prints. This enables each colour section to be cut from alternating prints to achieve the overrun. This method is probably good for fast cut colour changes, and for occasions when time is short (and the client will pay for the extra print).

31.8 PROCESSING

Tests can be first carried out in dishes or beakers with short film lengths, or an aerial film processor for 30 m (like the Doran Processor), or even a 1.7 m 35 mm spiral reel. Eventually the final processing can be done in any large spiral processor (there are several that can handle 30 m of film). A small scale processor used for microfilm, fluorography or for any simple 35 mm processor can be modified.

There are hundreds of recipes and hundred of test examples using a wide range of dyes and techniques needed to prepare an operational process, and anyone who tries will find that there was considerably more to both tinting and toning than just following a 1925 recipe. Detailed records kept with the examples must be kept as a reference collection to refer back to select, identify or research into the images produced.

Tinting is relatively straightforward, the depth of tone only dependent on solution concentrations, acid concentration, tint time, washing time, temperatures and agitation! Toning is a little more problematic.

31.9 SPECIFIC TECHNIQUES

31.9.1 Copper Red toning

Tests using the Eastman formulae show that the copper toning process does considerable damage to the film emulsion layer resulting in a blistered surface probably caused by excessive softening. Special hardening solutions using tannin are in some literature. However, some literature replaces copper toning by a form of uranium toning which produced a similar image colour, and eventually by mordant dye toning. It seems likely that early nitrate films suffered the same problems modern film stocks and that this was why other toning methods replaced it.

31.9.2 Uranium red–brown toning

Uranyl nitrate, like all uranium salts, is now very difficult to obtain. It is costly at £10 per gram, available from a few specialized sources and subject to quite onerous Health and Safety legislation (in the UK), even though as an 'unsealed radioactive source' its radioactivity is insignificant. It is also extremely toxic. In the 1920s uranium was not only a common toner but was also the basis of a very common mordant used as the starting point for a wide range of dye toned colours. Reid (1917) suggests that mordant dye toning could and should replace both copper and uranium because of toxicity and emulsion damage. As far as is known no one has used uranyl nitrate recently for a modern restoration, since all the mordant dye procedures can be carried out using potassium ferricyanide which yields silver ferricyanide as the mordant image, and a similar result.

31.9.3 'Sulphide' or sepia toning

Sepia was a common toner for paper prints until the 1950s and the image on paper varies from pale to dark red–brown. It was produced by bleaching the silver image to an insoluble halide salt and 'redeveloping' in sodium sulphide solution to silver sulphide which is red–brown but dense and opaque. When the process is carried out on a normal motion picture print the visual result is a 'cold' greenish black. If a very thin print was used a 'warm' tone not unlike copper toning was produced. This is extremely difficult to repeat and a modern low density print does not become as brown as the literature suggests. This may be due to differences in the modern print stock.

Sodium sulphide is an unpleasant and potentially dangerous chemical to use and needs good extraction and atmosphere testing. Mordant dye toning procedures seem to be the best alternatives today, and some original 'recipes' use a mixture of Iron Tone Blue and uranium ferrocyanide to produce a sepia, suggesting that the problems experienced today were present then.

31.9.4 The toning process

The earliest photographic toning processes used many process stages: wetting, bleaching, rinse, toner, wash, sometimes clearing bath and then a final wash. We chose to try first the shortest later processes. Even these can be quite lengthy – the so-called 'one-step iron-tone blue process' of Eastman (1928) was still wetting, bleach-tone, rinse, fix, wash. Mordant dye toning was almost always two-solution – a mordant-bleach, rinse and dye bath.

31.10 FINAL ASSEMBLY

This process is more labour-intensive than almost any other laboratory technique.

After colouring, the positive print may be cut together using a tape or cement splice, or in the case of polyester-based film, a so-called butt-welded join is possible which fits in the inter-frame line at each colour change. Every print has to be produced in this way. The procedure has all the disadvantages that any film of that period had – it has numerous joins, and the risk of a break, if the film is not on polyester base, is higher.

So called 'eight perf' 35 mm tape covers two frames completely, one on each side of the join, and even the most experienced viewers are unaware of the tape during projection. However, tape joins deteriorate in time and the adhesive spreads to coat adjacent film coils in a very unpleasant manner.

31.10.1 A practical method of making a tinted and toned restoration

Step 1 Two black and white prints are made.

Step 2 A record of the colours required is made listing the colour and the scene length.

Step 3 A new list is compiled showing the scenes of the same colour grouped together in series, each of length not longer than the longest length it is possible to tint at one time. An Excel program can be written to handle this decision process. Procedure is improved by ensuring that the scenes are in sequence in the small rolls when the scenes are 'head out'. This should be part of the Excel program plan.

Step 4 The film scenes from alternating prints of the same roll are cut and joined to make common colour sections, but with four to six frame 'handles' at start and end of each colour change, discarding the film between the handles. A two-reel vertical winder, with or without a synchronizer, is useful. The films are joined together with waterproof tape. Good records are essential. A printout from the Excel file should be used to provide the cut list, and the process should start from the end of each roll. At the end of this process there will be a collection of rolls each numbered and annotated with their colour requirement, head out.

Step 5 The film is then tinted or toned and dried, and wound up on separate well documented rolls, head out.

Step 6 Assembly is carried out by selecting the first scene from its roll, followed by the second and using a polyester joiner to join the positive film sections, removing and discarding the 'handles'. If the Excel list is well designed there need be no searching for scenes within any roll, as the next scene required will always be at the head of one of the rolls.

31.11 USING DUPLICATE NEGATIVES FOR OTHER RESTORATION

If a repeat restoration is never to be needed the over-run and pull-back frames can be removed to yield a normal duplicate negative (to print a black and white or a Desmetcolor print). Alternatively a normal black and white or Desmetcolor print can be made from the duplicate negative by direct printing, and the extra frames cut out of the resulting print.

If the print is on Estar base and welded butt joins used, there will be no increased risk of film breaks.

31.12 PASTEL TINTS

There are in some archive prints a range of apparent base colours or emulsion tints that are almost subliminal even when viewed over a lightbox and may be almost unseen on projection. These were first noticed by Noel Desmet of the Cinémathèque Royale de Belgique. There is no doubt of their existence, and the colours range from yellow to pink and sometimes green.

A few explainations for these faint tints are:

- That the original tint dyes have faded so much that the effect on projection has been lost.
- That they represent the last film processed in a progressively weak batch process and are therefore laboratory errors!
- That the base nitrate material has discoloured in time – this seems to be accepted by some technicians, but the range of hues is considerable.
- That the effect was intentionally almost subliminal – it is known that general colour fatigue can accentuate a colour change effect at a scene change.

None of the original papers of the period mention these pale tints.

31.13 PROCESS CONTROL

It is possble to establish a process monitoring system. No such system ever existed in the past, as far as is known, but as modern laboratory technicians we felt vulnerable without knowing how consistent our results are. A standard LAD print on black and white film stock can be used as the control image, the density of the LAD step to Status A measured and plotted as a trilinear display.

31.14 IDENTIFYING FADED DYES

It is possible to identify the original dye in some cases, to the extent that the original archive film can be measured and an attempt made to match its effect to a tested recipe or dye. With tints this works reasonably well and it is possible to identify whether the reproduction dye matches the original. The major problem exists with many metallic tones, which are relatively unstable dyes. Prussian Blue and the similar ferrocyanide iron tone colours such as the grass and olive green tones all darken and desaturate with time to become more neutral and more dense and also change colour to become more blue.

Prussian Blues
  Discolour in UV projector light
Uranium ferrocyanides
  Darken – may become redder/less yellow
Copper ferrocyanides
  Discolour with time to colourless?
Vanadium ferrocyanides
  No data – and difficult to recognize

Non-destructive testing is as yet untried as a means to identify many of these tones, although it does become possible to recognize certain effects. Simple destructive testing is mostly impractical or (although actually quite easy) because of the relatively large amounts of film needed to be certain. About two to five frames of 35 mm is needed for conventional inorganic 'Group analysis'. This is excellent for identifying the metal but because some mordant tone processes used uranium or copper ferrocyanides as the mordant for basic dye toning, the results need to be interpreted with care.

31.15 BETTER AIMS FOR DESMETCOLOR

The Desmetcolor process will always be less costly than restoration by the original tinting and toning, and will clearly be used for much routine work.

Using original recipes for tinting and toning produces images that can be used as master aim points for the Desmet system. However, we are now almost certain that some of the red dyes (e.g. Croceine and Amaranth and may be green tones such as Malachite) are outside the saturation achievable by mixing cyan, magenta and yellow in a subtractive colour print film.

32

Recording and reproducing the original tints and tones of *Quo Vadis* (1912): a technical case study[1]

32.1 MEASURING COLOUR

Soho Images tinting and toning service commences with an initial investigation into the original dyes used followed by a series of tests to establish which process to use for the restored print. Various methods of numerical evaluation were tried first by Nederlands Filmmuseum and by Soho Images as a means of recording the colour as found on the film, as a common technique for sharing data, as a method of identification, and as a control technique during the restoration. The method used to exchange data is illustrated by the tinting and toning of a print of *Quo Vadis* (1912), in spring 1997.

32.1.1 Methods

Colours are usually characterized by three components:

- **Hue:** the qualitative characteristic, i.e. hues of green, blue, orange, grey etc., principally related to the peak absorption wavelegth.
- **Saturation:** characteristic dependent on degree of other wavelengths present in a colour, i.e. the amount of white light present.
- **Brightness:** the over-all total amount of light transmitted.

There are many methods of measuring colour, including:

- **Matching** against coloured standard patches, e.g. Munsell or a paint chart.
- **Spectroscopy** analyses colours by providing measurements across the wavelength range, or solely by the peak absorption wavelengths, but does not indicate the visual appearence.
- **Comparators**, such as the Lovibond, measure the sample against a range of colours by mixing primaries to find a visual match.
- The **CIE** method plots colour as a position on a **colour space**, easy to measure with modern equipment but difficult to equate with a visual appearance.
- **Colour densitometry** measures colours in terms of the relative proportions of three stimuli (R, G, B) to create a colour. The stimuli can be correlated to the human eye (e.g. Status V or A) or to a photographic film sensitivity (e.g. Status M). The **trilinear display** of the densities indicates colour by position on a three axis graph which demonstrates the hue and saturation but ignores brightness. This is one of the the most useful display techniques.

32.1.2 Nederlands Filmmuseum

The NFM had been investigating methods of measuring the colour of the original film. In the past, records of tint or tone colours by the archives were often very imprecise, and if the film was later destroyed or decayed beyond recall, the effect was not identifiable. A simple statement 'blue' could mean a 'Cine Blue' tint or an Iron Blue tone, and tints and tones were sometimes confused in the past. Double effects were often not noticed and restoration from this information is not easy.

It was felt that a numerical value for the colour would significantly improve recording and enable subsequent restoration, and if the data was reliable and precise might allow identification of at least some of the original dyes.

The NFM were advised to try one of the new breed of computer operated devices used principally in the graphics and printing industry. They installed a Colortron, a simple hand-held spectrophotometer, comprising a small CD array, from the USA, interfaced to an Apple Mac and software designed to calculate a whole range of colour measurements from 'ink-weight' to the standard CIE tristimulus values. It can operate off any light source, normally an illumunated panel. The concept was attractive in that the CIE values generated could be plotted on the CIE diagram which indicates their colour within the visible range.

CIE plotted information is not very easy to interpret and many viewers find it difficult to associate a position on the colour space plot with a visual appearance.

The NFM Colortron could also display its results alternatively as Status A (see below) values, which enables the **trilinear display** to be used. This is a more 'user-friendly' display in which the visual colour is displayed and users soon learn to associate a position with a visual appearance. It is therefore very good for exchanging data.

However, it was found that the Status A values generated by the Colortron were incorrect, and did not match the standard Status A calibration system used as an international standard by Eastman Kodak, and this problem is still being investigated.

All the following data is therefore in the Status A format generated from Soho Images equipment.

32.1.3 Soho Images

Soho Images did not have Colortron equipment, but already used colour densitometry for process and printer control, measured on several different densitometers. The density measurement standard known as 'Status A' comprises three filters, red, green and blue, selected to correspond, in conjunction with the densitometer photocell, to produce values that indicate the visual appearance of the coloured transparent film sample.

The Colortron is not a particularly expensive unit but a modern Macbeth Densitometer for Status A is about £4000.

When R, G and B densities are plotted on a trilinear graph paper (not a technique normally used in photographic control) and this displays colour in a manner that is very similar to the way the human eye perceives. The brightness of the colour is cancelled out and only the colour and saturation is displayed, a measure of the character of the dye.

32.2 MEASURING THE COLOUR OF TINTED AND TONED FILM

32.2.1 Tints

With tinted film, readings were initially taken in the perforation area but it was found that this area was often damaged or more faded than the rest of the film, and gave inaccurate readings of the overall tint. However, since a tint is an overall colouring, anywhere on the image would give readings that would plot in the same position on a trilinear display, and cancel out the brightness.

32.2.2 Tones

Toned film has clear perforation areas, although this is not by any means always the case. Status A readings taken within the picture area vary in position on the trilinear display, since the image tone is proportional to the density of the original silver image. Choosing different areas of the print to measure produces a series of trilinear display positions that clearly indicate the hue as falling on one of the axes, but plots at different points radiating out from the centre. Any measurement will clearly define the hue.

32.2.3 Display of data

In Soho Images the trilinear display of density is used in two ways. The Status A readings and the trilinear display define the colour effect as it is today, and this provides a valuable record. The measurements help to identify a dye or 'recipe', and, once identified, to display both the identification and the restoration. This method was used by Soho Images to demonstrate the closeness of match between original dye and reproduction to the Nederlands Filmmuseum.

32.2.4 Control

The trilinear display and/or the R, G, B readings is also used as a control technique. A few frames of a standard print on black and white film (Soho Images uses the Kodak LAD print of a girl's head and grey steps) are cut onto the head of each roll of film prior to colouring. Taken off after colouring the print acts as a visual and a densitometric control for each colouring procedure. In the case of a feature film there may be 70–80 separate rolls of film to be coloured.

Poor correspondence with the aim agreed with the archive allows corrections to be made (it is a curious feature of tinting and some toning techniques that if the effect is too light it can be retinted, if too dark it can be washed out!).

32.3 IDENTIFYING THE COLOUR EFFECT

The number of dyes and formulae available to Soho Images are far less than the total of all the dyes and 'recipes' known to have been used. Some dyes are no longer available, but this is less than 20% of all those known to have been used. The majority of formulae no longer easily carried out today are the metallic toning procedures using uranium and vanadium. However, this leaves a considerable number of common procedures which can be reproduced, and so far we have yet to be certain that any tone we have seen before 1930 is definitely uranium or vanadium (uranium ferrocyanide was widely used on two-colour films in the 1930s).

Identification of a dye or colourant can be by one or more of the following, in decreasing order of precision:

1. Destructive testing of the dye to establish the chemical structure.
2. Characterization of the spectral absorption of the dye.
3. Identifying the visual colour match with a known existing dye.
4. Inspired guesswork (experience) from a knowledge of the most likely technique used at the time.

32.3.1 Destructive testing

This is beyond the financial capacity of the organizations involved for organic dyes as used for tinting and mordant dye toning, but quite practical for metallic tone colours.

Conventional inorganic qualitative analysis 'by group' is all that is needed to identify iron, uranium, copper, and vanadium, and inferring the presence of their ferrocyanides. This form of analysis can be done in small test tubes if enough sample film is used, or in micro equipment if only small pieces are used. About 1 cm^2 of film is needed as a minimum. The film is soaked in water to soften the gelatine, then the emulsion is removed with 3N NaOH solution, just enough to cover, taking about 2 hours. Heating is not usually required.

The resulting solution or dispersion, after removing the film base, is then filtered or decanted and the solution treated (very carefully) with an equal volume of 3N nitric acid. The resulting acid solution is then subjected to the usual inorganic group analyses for metal salts. In the case of Iron Tone Blue the metal identifies as iron alone. Many other colour tones key out as iron (from the ferrocyanide ion used as the bleach), and one other metal.

32.3.2 Spectral absorptions

We have some spectral absorption data on dye stuffs from as early as 1909, and the procedure for measuring these is usually a spectrophotometer, which is sometimes available in a film processing laboratory because it is used for process solution component analysis. Most spectrophotometers for quanitative analysis are very accurate, however are not easy to use for qualitative work where a plot of the density to different wavelegths is used. Peak wavelength absorption is useful and reasonably easy to measure. The dyes in a film sample should be extracted from the film otherwise base density, image density and mordants may all add to the measured values.

32.3.3 Visual matching

Visual matching by comparing the colour of the original effect with a modern process using an original formula is very imprecise by eye. The old tints often become cloudy, diffuse or slightly opaque with age ('laking') and some, Iron Tone Blue and perhaps other metallic tones, darken and desaturate with age. Only numerical values of density allows colour to be plotted on a trilinear display and ignores the overall density. Status A seems a reasonable method of making these comparisons.

32.3.4 Experience

Once seen and identified, many of these effects are recognizable again. The various blue iron tones vary with the formula and whether the film was 'fixed' out. Inevitably a degree of 'I've seen that before' enables us to make a test to prove that an effect was produced in a particular way. The mordant green of the last scene of *Quo Vadis* was recognized as Malachite Green before the test procedure proved it.

32.4 RESTORATION OF *QUO VADIS* (1912)

32.4.1 Introduction

Quo Vadis (1912) was reconstructed as a Lumière funded programme, a joint venture between the Cineteca Italiano, Milan, the Nederlands Filmmuseum (NFM), Amsterdam, and the National Film and Television Archive, London.

Once reconstruction was complete, Haghefilm in Amsterdam made an optical duplicate internegative on Panchromatic Duplicate Negative film directly from the original prints which were tinted and toned throughout. The film was in a very poor condition, badly fragmented and brittle, so parts were already badly duplicated. The resulting duplicate negative was as good as could be expected from the state of the original film.

Some of the resulting duplicate negative material was several generations further from the original material than other sections and was considerably less satisfactory, appearing '**dupy**'. This term summarizes the overall visual appearance of low resolution, grainy high contrast images lacking in fine detail that characterizes multigeneration results.

An initial print was made by the Desmet method of double pass printing. Later the NFM made the decision to ask Soho Images to evaluate some fragments of the original tinted and toned material to see if reasonable information could be obtained sufficient to tint and tone a print using original formulae. The NFM sent Soho Images a fragment of each of the colour effects they recognized as different, together with the duplicate negative to prepare test prints and test effects.

32.4.2 First sight

We received a complete negative of the feature plus a short compilation roll consisting of a scene of each colour required. We also received a set of samples of the original tints and tones on nitrate stock. We were asked to produce a copy of the test roll, reproducing the tint and tone colours of the samples.

The set of sample frames showed 11 colour/colour combinations: 9 tints, 1 tone and 1 tint + tone. When measured on the Macbeth densitometer using Status A filters the density readings were as follows:

	Red	Green	Blue
Blue/green tint or tone?	1.23	0.19	0.29
Green tint	0.61	0.19	0.29
Light green tint	0.22	0.10	0.19
Yellow tint	0.03	0.08	1.17
Yellow/orange tint	0.15	0.51	1.00
Light orange tint	0.04	0.70	1.03
Dark orange tint	0.13	1.38	2.22
Red tint	0.04	1.88	1.42
Salmon tint	0.04	0.52	0.43
Salmon tint (+ blue tone)	0.03	0.41	0.37
Blue tone	Standard Iron Blue		

These colours are shown plotted on the trilinear chart (Figure 32.1).

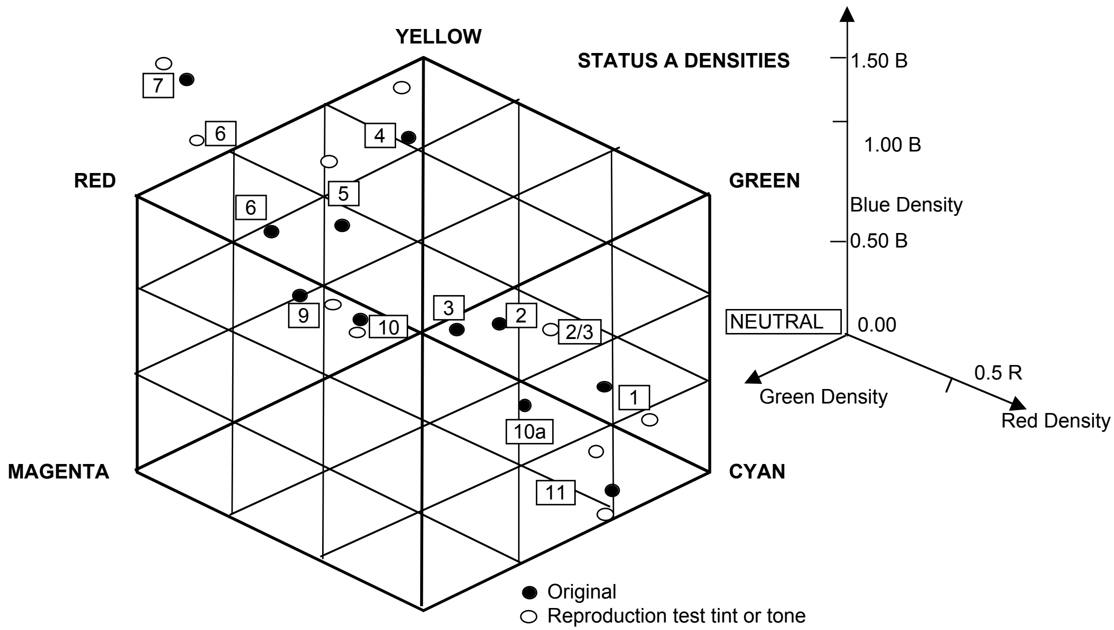

Figure 32.1 Comparison of *Quo Vadis* original tints and tones and tests of reproductions

32.4.3 Choice of correct tint

We produced a set of tinted and toned samples and reported to the NFM as follows:

- **Blue/green tint?** We have not found a single dye which gives a good match for this tint. Tests have shown that a mixture of Napthol Green and Patent Blue give an acceptable colour match. Both dyes are listed by Kodak in the early 1920s under the terms 'Cine Green' and 'Cine Blue Green'. This effect concerned us as it was not easily recognizable and seemed not to be a simple tint.
- **Green tint:** Although the original is faded we found that Napthol Green gave a reasonable colour match.
- **Yellow tint:** A good match produced by Quinoline Yellow – 'Cine Yellow' (Kodak 1920s).
- **Yellow/orange tint:** A mixture of Quinoline Yellow and Crocein Scarlet ('Cine Scarlet'. Kodak 1920s) produced a match for this tint.
- **Light orange tint:** A different mix of Quinoline Yellow and Crocein Scarlet matched this tint.
- **Dark orange tint:** A more concentrated solution of the Light Orange dye mix gave this tint.
- **Red tint:** A dye mixture of Quinoline Yellow and Amaranth ('Cine Red', Kodak 1920s) produced a reasonable match for this tint.
- **Salmon tint:** A weak mixture of Quinoline Yellow and Amaranth gave a good match for this tint.
- **Salmon tint/blue tone:** A stronger solution of the previous salmon dye was required to produce a similar density tint on this standard Iron Blue tone (Kodak. 1920s).
- **Blue tone:** The Eastman Kodak chemistry of the early 1920s has produced a bright blue tone. Because a predictable chemical reaction is used for this tone we can assume that the original material has faded from a much brighter colour.

Samples were sent to the Filmmuseum for evaluation. They replied favourably but asked for some minor changes, as follows:

- The **green and light green tints** needed to be combined and made slightly more

blue/green. This was achieved by using a mixture of Napthol Green and Patent Blue.
- The **red tint** needed to be more red. This was achieved by using a single dye solution of Crocein Scarlet.
- The **yellow/orange tint** needed to be slightly more yellow to distinguish it more from the two other orange tints. Minor changes in the ratio of Quinoline Yellow and Crocein Scarlet produced a more acceptable tint.

32.4.4 Blue/green effect

Just prior to colouring the test roll we, at Soho Images, had further discussions regarding the **'blue/green tint'** and decided that the overall appearance of the picture area resembled blue/green dye toning tests we had recently carried out (taken from Reid, 1916, and from an Agfa publication, probably of 1926). These tests were shown to the Filmmuseum who, in turn, asked us to proceed as we thought correct. We therefore changed the blue/green tint to a **blue/green dye tone** using Malachite Green. We achieved a good visible match with the original sample by not completely clearing the highlights by long washing.

32.4.5 Processing the test roll

There was less than 100 ft of each tint so we needed to process one spool for each colour. We had some initial density problems in transferring the process from the testing stage to the production stage but these were quickly resolved and a test roll produced.

When we projected the test roll it was apparent that the salmon tint on the Iron Blue tone did not have sufficient density, although we had matched the original sample (see Figure 32.1). We re-tinted the scene to a higher density and found it more acceptable.

The completed test roll with 11 colour effects was returned to the Filmmuseum for their appraisal.

The Filmmuseum accepted our test roll with one change, i.e. that the light orange tint (2.1.5) did not show when projected with an xenon light source so they would prefer a darker orange tint, similar to the dark orange (2.1.6) for those scenes.

32.4.6 Processing the whole feature

We proceeded with colouring the whole feature; it required over 70 spools of film to complete the tinting and toning using our traditional procedures.

The completed print was despatched from Soho Images at the end of March 1997.

32.5 IN CONCLUSION

The process of identification of tint and tone effects will increase with experience but principally by carrying out all the formulae in the original papers, keeping samples and measuring them (to Status A).

Status A and trilinear plotting is a fast practical procedure for archives and laboratories that enables them to exchange precise information (whether for restoration by tint and tone or by Desmetcolor). If the Colortron can be used this will be a cheaper alternative to a Status filter densitometer.

The CIE display method is good in principle but even in the hands of experienced technicians is difficult to interpret in terms of visual colours.

Some form of colour measurement is necessary since old film tints and tones change in transparency as they age, even if the colours do not greatly alter.

Some measure of guesswork followed by practical testing is necessary to define some of the iron and other metallic blue tones. They are immediately recognizable, have almost always darkened with time but vary in formula and therefore in original appearance.

Note

1. Parts of this chapter are based on a Soho Images report to the Nederlands Filmmuseum.

33

The Desmet method for restoring tinted and toned films

33.1 EARLY COLOURED FILM RESTORATIONS

Restoration of coloured monochrome films was, until the 1960s, carried out almost exclusively by conventional black and white duplication and the colours were simply recorded in writing. Little attempt was made to reproduce the original colours for archival storage or for display. During the 1960s, and up to today, a colour internegative made on the current Eastman Colour Internegative film was, and still is, the most frequent means of copying the coloured images The earliest attempts were usually poor and of too high a contrast but today a closer visual match to the archive original can be achieved. Some laboratories use camera negative films for some purposes, especially for stencilled prints, for the more faithful rendition of pastel colours, especially reds and pinks. The resulting colour print represents the colours left in the film today after whatever fading has occurred, and for many years archivists have had reservations about recording these images in their faded state, rather than seeking to reproduce the pristine image.

In many cases the original print is too high in contrast to be printed onto Colour Internagetive without some reduction of contrast by 'flashing'. The technique used has become a standard for the reduction of contrast.

The limitations of Colour Internegative are therefore as follows:

1. Fixed contrast, and only alterable by flashing, within certain limits.
2. The image recorded is a record of the present faded condition, rather than a restoration of the pristine print.
3. Subtractive dyes are restricted in the saturations achievable, some of the old tint and tone dyes are outside the range.
4. Colour Internegative is a costly film stock.
5. Colour films have less archival permanence than a black and white record.

33.2 DUPLICATION OF HAND COLOURED AND STENCILLED FILMS

In stencilled films and other systems in which discrete patches of colour are applied, the use of colour internegative is really the only photographic method possible, producing a copy of the original in its probably faded state. Only digital restoration can provide better restorations.

The procedure for reproducing a copy of a coloured print is exactly the same as for any print duplication using an integral tripack such as Eastman Colour Internegative film, and setting up needs the rigorous application of the LAD system for optimum results.

33.3 DUPLICATION OF TINTED AND TONED FILMS

Other coloured films are less discrete in their colour and either the entire frame is suffused with one colour (tinting), or the image is coloured a single colour (toning), or a combination of the two techniques was used. In these cases a wider range of techniques for restoration exists.

1. **Copying the original onto Eastman Colour Internegative,** and the resulting colour negative is printed onto a modern colour print stock.
2. **Digital film–tape–film transfer,** so far largely untried.
3. **Using the original tinting or toning technique on modern print stock.**
4. **Printing a black and white duplicate negative onto colour print stock.**

The single pass method is unfortunately still widely used, but this chapter describes the double pass method, which is capable of a wide range of effects.

33.4 SINGLE PASS PRINTING

Any black and white duplicate negative can be printed onto a conventional **modern colour print film** to achieve an image of almost any colour (achieved by varying the grading with filters or light valve settings) from a neutral black or grey, to any saturated primary. This does make it possible to achieve quite good matches with many of the tone colours that were available.

However, by this 'single pass' method it is not possible to copy satisfactorily tinted films or double toned or tinted and toned films. If the image is printed somewhat dark an effect not unlike tinting can be achieved but the image loses much of its aesthetic value. The overexposure has the effect of producing hazy monochromes and the results obtained from this method are simply not of high enough contrast and the high densities are not black but simply a denser colour. Occasionally good results are obtained, but the effect is best with blues and day-for-night shots, and other colours are very difficult to achieve.

There is no doubt that in certain circumstances where a film is entirely toned in a variety of strong colours, especially if the colours were produced by colour development or by mordanting, this simple and inexpensive method is very effective. The negative can be graded visually using a colour analyser (Debrie, Filmlab Colour Master, or Hazeltine) without difficulty.

33.5 DOUBLE PASS OR 'DESMETCOLOR'

This system, devised by Noel Desmet of the Royal Belgian Film Archive, has been used since the 1970s to try to restore some of the strong colours and dramatic effects of early tinted and toned prints, without the cost of using a colour intermediate film. It is not intended that Desmetcolor be used to precisely match the colours of a particular print. The method provides an extensive palette from which to select colours. This is particularly useful in those cases where only a duplicate negative is still in existence, and when notes had been kept of the colours of the original nitrate print before it had been destroyed. Noel Desmet's method enables these colours to be put back as tints or tones or as a combination using the archive duplicate negatives as a starting point. Although the colours were not intended to specifically yield a match with the originals, if enough trial and error time is spent, quite close matches are possible. The overall dramatic effect is probably very close to that of the original. A number of laboratories use this method today.

Working independently, Dominic Case in Australia has used a similar system but making the monochrome duplicate negative on Eastman Colour Internegative (*SMPTE Journal*, 1987; see Bibliography). The choice of material was probably influenced by the idea that a masked negative material would make a more stable starting point than a black and white negative and make grading and analysing reasonably straightforward. Comparisons of the two methods suggest that the results are very similar but the use of a black and white negative material results in finer grain on the final print, and the Desmetcolor is considerably lower in cost.

33.6 THE DESMETCOLOR PROCESS

Noel Desmet commenced his work to find an alternative procedure to using a modern colour negative partly to reduce the cost of

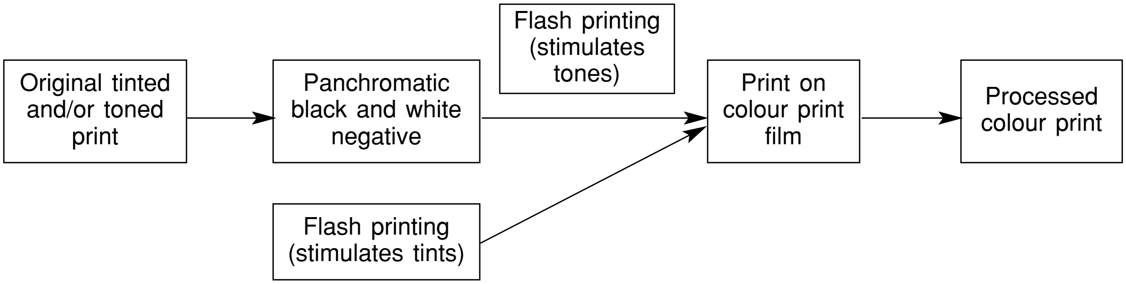

Figure 33.1 The 'Desmetcolor' process

colour internegative and also to restore early coloured films that had faded. Colour negatives could only copy the existing faded result.

The procedure (illustrated in the colour plates section) is as follows:

33.6.1 Making a duplicate negative

Starting with an original tinted, toned or combination nitrate print a black and white negative is produced on a panchromatic emulsion such as Eastman Fine Grain Duplicating Panchromatic Negative Film 5234 set up to achieve a contrast (gamma) of about 0.50. This gamma seems to be a good starting point but a higher contrast is preferred for some eventual colours.

33.6.2 Selecting the colours for tone or tint

A series of colour tests are made by printing a piece of film base of the material used for the negative onto a colour print film (such as Eastman Colour Print) at various printer light settings on a rotary contact additive lamphouse printer (such as a Bell & Howell Model C). A good method of establishing a starting point for the range of colours is to put the test film base onto a video colour analyser and vary the exposure settings to see the effect of a flashing exposure.

It will be found that many of the best effects are achieved by setting one printer light valve to zero (i.e. using the zero close facility) and varying the other two relative to each other. Strong colours can be obtained and they are quite repeatable. The colours selected can be selected for two different purposes – to create a coloured image simulating a toned image, and to create an overall tint that simulates the tint colours.

33.6.3 Printing the duplicate negative: toned prints only

In the same rotary printer the duplicate negative is printed onto the colour print film at a setting of the light valves needed to produce the tone colour required. Generally little or no scene-to-scene grading is required if the original was a graded print and the duplicate negative procedure was well set up and was exposed at a single light setting (i.e. was a one-light duplicate). Some trial and error may be needed to achieve this or the negative can be scanned in a video analyser. If scene-to-scene grading is required then the ratio of the R, G and B setting must remain the same throughout the sequence. Even so, grading by this technique is not advised as the colour does change slightly from scene to scene.

On processing, the image will be a monochrome of the colour selected with the unexposed areas remaining white.

33.6.4 Tinted prints

On the same rotary printer the black and white duplicate negative is printed to a neutral grey image on colour print film (this, too, can be established on a video analyser) in the first pass through the printer. The print film is then passed back through the printer (i.e. a second pass) and exposed to an overall flash exposure (in much the same way as preflashing to reduce contrast) at printer light valve settings chosen for the colour of the tint produced.

On processing, the image will be monochrome black and white suffused with a tint over the entire frame area. The black image areas will be black and the unexposed highlight areas coloured.

33.6.5 Tinted and toned combinations

Starting from the black and white duplicate negative a colour image is printed in one pass through the printer onto colour print film, followed by a second pass of the print film alone to produce the tint colour background. The effects of this combination effect are not entirely predictable but certainly do give subtle results very similar to the early combination prints.

33.6.6 Intertitles

Both the Desmet and the Case methods are capable of refinement for production purposes to produce multiple prints or to introduce conventional intertitles by operating the two passes as an A&B roll printing system. Nor is it difficult to produce different language versions, or different intertitle versions in just the two passes needed. The duplicate negative constitutes the A roll and is exposed to generate the neutral or coloured (toned) image. Black spacing is cut in where any titles are to be printed from the B roll. Another roll of clear film (with intertitles cut in if necessary) would constitute the B roll and be used to create the background tints, with the intertitles inserted at the A roll black spacing positions.

If different language intertitle versions are needed a new B roll can be prepared. With a modern printer using FCC or punchtape the A roll could be exposed in one direction and the B roll in the reverse direction, avoiding any rewinding of stock in the dark, with its associated risks.

33.7 CONCLUSION

The benefits of this procedure are in cost, choice of effect and the easily achieved control of contrast. The effort required is similar to that of a fully graded colour print from a colour negative printed ‘A&B’ and the pricing of the service by a laboratory is similar.

As more investigation is carried out into the original dyes it seems that it may be possible to estimate the degree of fading that has occurred and this method provides the only mechanism for reproducing different colours from the originals and therefore correcting for fading.

Desmetcolor has drawbacks, not least because colour film is still used for the print. However, the resulting image may be no less stable than the original dyes.

One aspect also being investigated is the ability of Desmetcolor to produce the strong saturated colours of some of the dyes used in the early years of the cinema, but which have faded over the years. Noel Desmet has reported success in reproducing the colour of vivid ‘fixed’ Iron Blue as produced with the original chemistry. Soho Images have reported that some saturated red and green dyes used for tinting and toning may not be accurately reproduced. This is not surprising – cyan, magenta and yellow subtractive primaries are limited in the range of colours possible. Inevitably, due to these limitations of cyan, magenta and yellow as primaries, not all hues and saturations are going to be possible, but certainly more of the saturated colours are possible by Desmetcolor than by any other colour print film technique.

34

Laboratory Aim Density values and other useful data for duplication

34.1 COLOUR FILMS

On the Kodak Standard negative the LAD Standard Patch Status M densities are:

R	0.80
G	1.20
B	1.60

The characteristic curve of 5247 shows that these densities are chosen to be exactly mid scale between highlights and shadows.

When printed correctly on Eastman Colour Print Film 5384 the LAD Standard Patch will measure on Status A:

R	1.10
G	1.06
B	1.03

(This is a neutral grey of 1.00 visual density on the print (1.00 END) for a xenon arc projection light source.)

A master positive on Eastman Colour Intermediate Film 5243/7243 will measure (Status M):

R	1.10
G	1.50
B	1.90

A duplicate negative Eastman Colour Intermediate Film 5243/7243 will measure (Status M):

R	0.90
G	1.30
B	1.70

A master positive on Eastman EXR Colour Intermediate Film 5244/7244 will measure (Status M):

R	0.90
G	1.30
B	1.70

A duplicate negative on Eastman EXR Colour Intermediate Film 5244/7244 will measure (Status M):

R	0.90
G	1.30
B	1.70

An internegative on Eastman Colour Internegative 5272/7272 will measure (Status M):

R	0.90
G	1.30
B	1.70

34.2 USING LAD FOR BLACK AND WHITE DUPLICATION

Black and white duplication follows exactly the same principles but requires the control of only one density value.

Original B/W negative (Status V)	D 0.65
B/W Fine Grain positive (Status V)	D 0.75
B/W Fine Grain negative (Status V)	D 0.75

34.3 EASTMAN COLOUR REVERSAL INTERMEDIATE FILM

LAD data for Eastman Colour Reversal Intermediate Film 5249/7249 is a useful reference for checking existing archive duplicates. The stock was used to produce duplicate colour negatives in a single printing operation.

The film was a colour reversal stock with an integral mask and a contrast of 1.0. It was discontinued in 1993 as the quality of the resulting duplicate was not as good as one made by the two-stage intermediate process, due to image streaking, process inconsistency and poor curve tracking.

If the LAD print has been left on the front of the duplicate negative it will be possible to measure the densities of the LAD patch to see if the duplicate has been correctly exposed. Using the standard printer light above, a correctly exposed CRI will have LAD patch print-through densities of:

R	0.90
G	1.30
B	1.70

Note that these densities are each 0.10 higher than the 5247 patch. This means the CRI LAD patch will print 4 Bell & Howell printer lights higher than the original 5247 patch. Therefore, when checking full graded CRIs for colour/density on a colour analyser, a good guide is that a CRI should print at approximately 29–29–29 if the laboratory standard printer light for LAD is 25–25–25.

34.4 OTHER USEFUL LAD AIM VALUES FOR OLD STOCKS

'Ektachrome' Commercial 7252:

R	1.10
G	1.10
B	1.10

Colour Internegative 5271/7271:

R	0.90
G	1.30
B	1.70

Colour Positive Print 5281/7381 and 5383/7383:

R	1.09
G	1.06
B	1.03

34.5 DENSITOMETER VARIATIONS

There may be differences in responses among densitometers. Apply any densitometric difference between Kodak's responses and a particular densitometer, if known. However, these differences are usually negligible, especially for making intermediates.

34.6 DENSITY CORRECTIONS AND GAMMAS

Since the various film stocks have different gammas, or contrast, a change of one printer point will not always result in the same density change. The approximate gammas of the more common colour films are:

Film	*Gamma*
5291/7291 (used as an internegative)	0.60
5249/7249	1.00
5243/7243	1.00
7252 (used as a printing master)	1.20
5272/7272	0.50
5384/7384	2.00 (midscale, near LAD)
7389/7399	1.00
7390	1.40

34.7 DENSITY CHANGES

Below is a chart showing the approximate density expected when various exposure adjustments are made:

Film stock	*Change in density (midscale) with change in printer points*			
	+1	*+2*	*+4*	*+8*
5291/7291	+0.02	+0.03	+0.06	+0.12
7252	–0.03	–0.06	–0.12	–0.24
5234/7243	+0.02	+0.05	+0.10	+0.20
7389	–0.02	–0.05	–0.10	–0.20
7399	–0.02	–0.05	–0.10	–0.20
5272/7272	+0.01	+0.02	+0.05	+0.10
7390	–0.04	–0.07	–0.14	–0.28
5384/7384	+0.05	+0.10	+0.20	+0.50

35

Duplication of colour negatives using colour intermediate film stocks

35.1 PREPARATION OF THE MASTER POSITIVE (INTERPOSITIVE)

Step 1 Monitor and adjust the process for Eastman Colour Intermediate film to be certain that it conforms to the manufacturer's specifications. This is very important since any photographic variation from standard in the colour master positive stage will be multiplied in the colour duplicate negative stage.

Step 2 Prepare a printer test or test loop containing an original colour negative control strip, and a few selected frames from the work.

Step 3 Measure the Status M densities to blue, green and red light for the negative control strip. Also measure if possible the highest and lowest integral densities in the picture area of the selected frames.

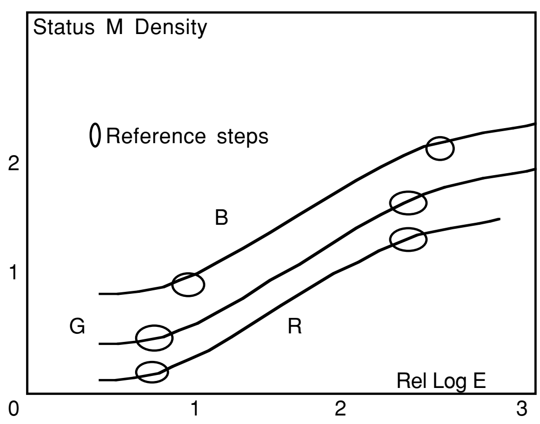

Figure 35.1 Eastman Colour Negative film: original colour negative control curve

Step 4 Plot the characteristic curves for the negative control strip and designate the steps whose densities correspond with the highest and lowest densities of the picture area. These will be the reference points throughout the duplication procedure and represent the picture density range which must be reproduced .(See Figure 35.1.)

Step 5 Print the test loop onto colour intermediate film.

Step 6 Process the printed test loop footage in a standard process.

Step 7 Measure all of the integral densities to blue, green and red light of the control strip and the corresponding densities of the reference steps of the printed strip.

Step 8 On the characteristic curves for the control strip locate the positions where the densities of the reference steps of the printed scale occur on these curves. (See Figure 35.2.)

Step 9 If the picture density range does not fall on the linear portion of the sensitometric control curve, the printer exposure must be adjusted. If exposure adjustments needed for all three curves, removal or addition of neutral densities from the filter pack or adjustment of the printer light settings is called for. If exposure adjustments are needed for the individual blue, green and red curves,

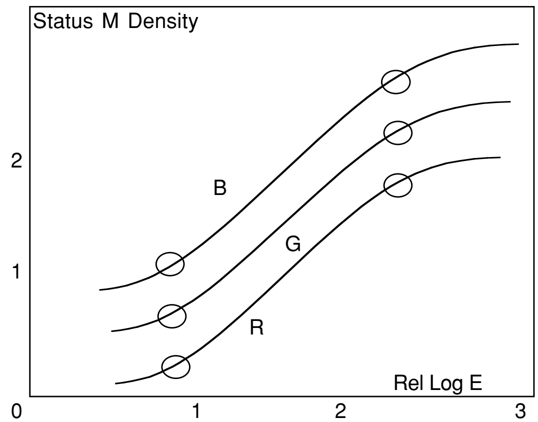

Figure 35.2 Eastman Colour Intermediate film: colour master positive control curve

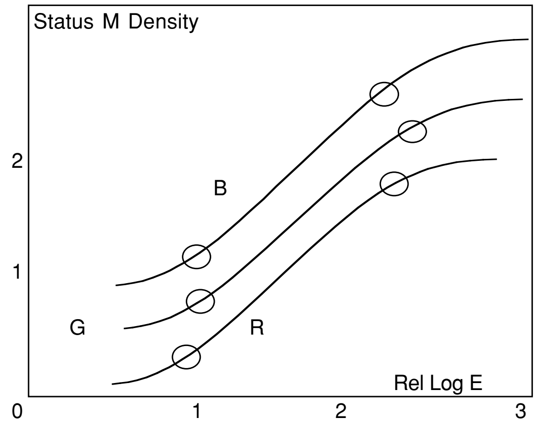

Figure 35.3 Eastman Colour Intermediate film: colour duplicate negative control curve

the filter pack must be modified by removal or addition of yellow, magenta or cyan filters respectively, or the printer light values altered.

Step 10 When the optimum printing level has been established print the original negative picture footage at these settings.

35.2 PREPARATION OF COLOUR DUPLICATE NEGATIVE

Step 1 Print the colour master positive (the correctly exposed print-through from Step 10 above) onto colour intermediate film. A step printer of either the contact or optical type should be used at this stage.

Step 2 Process the print-through in a standard process for colour intermediate film.

Step 3 Measure the integral densities to blue, green and red light for the reference steps of the printed scale.

Step 4 Plot the characteristic curve for intermediate film and locate the positions where the densities of the reference steps of the print-through plot on these curves.

Step 5 If the picture density range does not plot on the linear portion of the control curve, the printer exposure should be adjusted (see above).

Step 6 When the optimum printing level has been established, print the master positive picture footage and grey scale onto colour intermediate film.

36

Duplication of colour prints using colour internegative (or camera negative) film stocks

36.1 INTRODUCTION

This procedure can be used for any colour print, tinted and toned, hand coloured or stencilled. The same method can be followed using camera negative films which may be finer in grain and whose layers may track better than the old Eastman Internegative film. Camera films must be handled in total darkness.

36.2 PROCEDURE 1: GRADING AT FINAL PRINTING STAGE ONLY

36.2.1 Set-up procedure

Step 1 Plot the curves for an internegative control strip whose process is on aim (Status M) and make up the strip as a loop or length for printing.

Step 2 Measure the highest and lowest integral densities to blue, green and red light for typical scenes of the picture footage to be duplicated. Provided a frequent check is carried out the reference steps can be considered permanent for a particular type of print original.

Step 3 Indicate on the control curve the step numbers whose densities most closely match the highest and lowest picture densities above – physically mark these steps on the control strip as they will act as reference steps for the duplication process.

Step 4 Print the colour print control strip onto colour internegative film.

Step 5 Process the printed strip in a normal process for the film, usually ECP-2.

Step 6 Measure the integral densities to blue, green and red and the reference steps of the printed strip (Status M).

Step 7 Plot the characteristic curves for the control strip and mark the positions for the densities of the reference steps of the print-through.

Step 8 The reference steps should plot on the linear portion of the control curves. If they do not, an adjustment in the exposure must be made. Colour adjustments can be made by using filters or adjusting additive printer light settings or trim settings.

36.2.2 Production

Step 9 When the exposure levels have been adjusted, the picture footage is printed onto the internegative.

Step 10 Print the internegative on colour print film using normal grading methods.

36.3 PROCEDURE 2: GRADING AT INITIAL PRINTING STAGE ONLY

36.3.1 Set-up procedure

Step 1 Monitor and adjust an ECP-2 process until on aim for internegative.

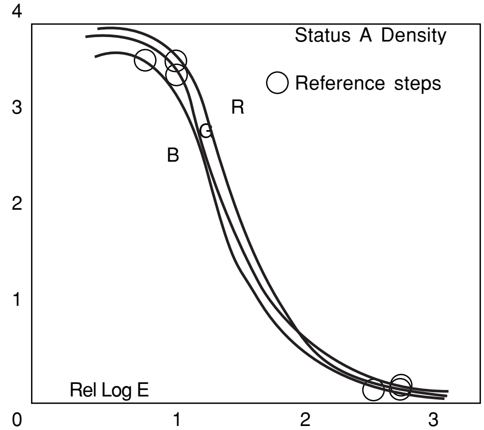

Figure 36.1 Colour reversal original or a 'print through' curve of a projection print

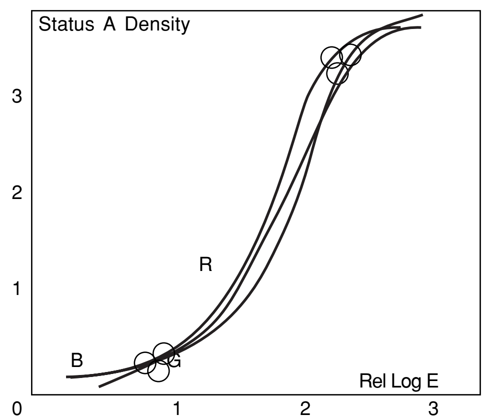

Figure 36.2 Colour print film

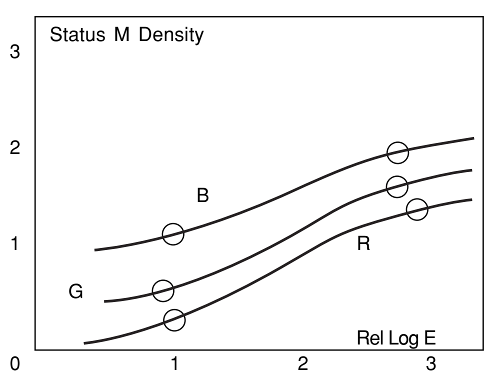

Figure 36.3 Eastman Colour Internegative film control curve with reference steps

Step 2 Print a standard Eastman Colour Internegative strip on an automatic additive printer with the trim controls and main controls set centrally (if B&H trim: 12–12–12; main: 25–25–25).

Step 3 Process.

Step 4 Plot a full internegative curve and mark off the print-through densities of the highest and lowest patch densities of the standard Internegative original for all these colours.

Step 5 Assess the R, G, B shifts required to fit the standard original range onto the centre of the straight line portion of the internegative curves.

Step 6 Adjust the *trim* controls of the printer to achieve this and record these values.

Step 7 Repeat Steps 2–4 until correct positioning on the internegative curves is achieved.

36.3.2 Setting up the printer

Step 8 Produce the best possible print from internegative on colour print film on any printer (high speed additive preferred). An analyser can be used for this.

Step 9 Record which printer, RGB trim and main controls are used for this, and the batch of print film.

36.3.3 Setting up the video colour analyser

Step 10 Produce the best possible print from original standard internegative on colour print film This should print at 25–25–25.

Step 11 Set analyser to show a matching print on *reversal* setting with main controls at 25–25–25 by adjusting analyser trim controls.

(This is the normal setting up procedure for an analyser.)

36.3.4 Production

Step 12 Analyse originals on the analyser as if they were to be printed on a reversal print stock (insert standard internegative as a check – should analyse at 25–25–25) and produce punch tape.

Step 13 Print production originals onto internegative using a duplication printer with trim settings as defined in Step 6 and grading data produced in Step 12.

Step 14 Print production internegatives on the final stage printer with trim and main controls as recorded in Step 9.

Note

Some graders pre-grade the originals visually, and then use the *analyser* values to produce the printer light settings in Step 12.

37

Black and white separations for duplicating, preserving and restoring colour negatives and prints

37.1 INTRODUCTION

In this system (originally widely used from the time of its publication in 1947 by Eastman Kodak, but now rarely employed for its original purpose) black and white separation positives are made from an original colour negative. The process was a development of the many three-strip colour camera systems in use from about 1930. The master positives can be stored. If, later, they are to be reconstituted to create a new negative, they are printed in register onto a multilayer colour film to give the colour duplicate negative. This system has the advantage of providing a more or less permanent record of the valuable original because of the keeping characteristics of processed black and white films. Where negatives differing in size from the camera negative are required, the operation of printing in register three black-and-white positives is both difficult and expensive.

Archive laboratories use both the original commercial process and derivatives of it. The black and white film stocks used were originally designed for duplicating masked colour negatives but are also used to make separation negatives from unmasked colour negatives, colour prints, or any other colour intermediate or even a coloured nitrate film. These derivative processes are generally used to correct for faded dyes and are described later.

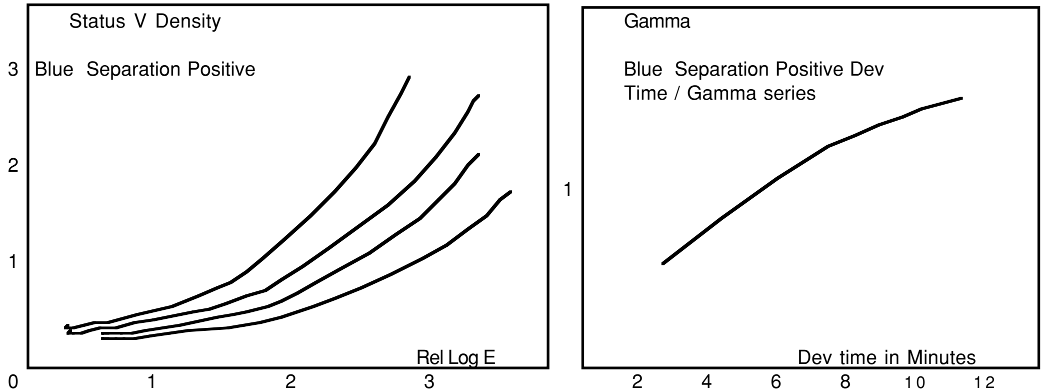

Figure 37.1 Eastman Fine Grain Panchromatic Separation film

37.2 PROCEDURE

The initial step in the system utilizing black and white or master positives is to prepare the time–gamma curves for the material being used. A set of sensitometric control strips is exposed using the same intensity level and filters as would be used in printing picture material. These are the tricolour filters. The strips are processed for a series of times in the equipment regularly employed for processing picture footage.

The densities of the strips are measured and the corresponding characteristic curves for exposure to blue, green and red light are plotted. The gamma value for each curve is determined and time–gamma curves are also plotted. These time–gamma curves are used later in the procedure to permit choice of the appropriate development time for a specified gamma.

For the first trials it is desirable to duplicate only a short length of original colour negative. It is most convenient to prepare a **printer test loop** consisting of a processed colour negative sensitometric strip and a few frames of the scenes to be duplicated.

37.3 DETERMINATION OF MASTER POSITIVE CONTROL GAMMAS

In the usual case, when duplicating a colour negative, it is required that the colour duplicate negative will have the *same* contrast as the original negative. Following the Contrast Rule, which defines that contrasts multiply when copied photographically, this means that the overall gamma of the duplicating step should equal 1.0.

If SP represents the gamma of the particular separation positive and DN represents the gamma of the colour duplicate negative, then:

Separation positive gamma ×
Duplicate negative gamma = 1.0

$$\text{SP} \times \text{DN} = 1.0$$

Since DN is fixed by the particular emulsion number of the colour duplicating material being used and the processing of this material, we can determine the correct gamma for each of the separation positives by the relationships:

$$\text{SP (blue)} = \frac{1}{\text{DN (blue)}}$$

$$\text{SP (green)} = \frac{1}{\text{DN (green)}}$$

$$\text{SP (red)} = \frac{1}{\text{DN (red)}}$$

In practice these equations have to be modified further because the print-through gammas of the separation positives are not the same as would be predicted on the basis of the integral densitometer measurements. These printing factors (PB, PG and PR) associated with each of the separations when printing onto the colour duplicating negative film are to take into account the flare and other influences on the image contributed by the printer. The above equations then become

$$\text{SP (blue)} = \frac{1}{\text{PB DN (blue)}}$$

$$\text{SP (green)} = \frac{1}{\text{PB DN (green)}}$$

$$\text{SP (red)} = \frac{1}{\text{PB DN (red)}}$$

Initially it is convenient to assume that PB, PG and PR are each equal to 1.0, and to make a more precise determination later in the procedure.

The step-by-step determination of the required control gammas for the separation positives is as follows:

Step 1 Obtain a sensitometric control strip for the original colour negative process. (If the original negative being duplicated is an old **archival negative**, of a long defunct process the best procedure has been found to be to use a modern colour negative control strip, if the original being worked on is a masked negative. If the original is an **unmasked negative** it is better to use a colour print film strip, and some laboratories use a modern colour print film strip with a relatively neutral grey scale for this purpose. Print films have much higher maximum densities and higher contrasts than any negative film has ever had and it is essential to recognize that this film strip is simply a set of densities that will be used as a guide to represent the densities of an old negative.

Step 2 (Optional) Measure the integral densities of the steps of the control strip obtained in Step 1, to blue, green and red light and plot the corresponding characteristic curves. This is not an essential step, but useful to see the positions on the curve of the fixed points established later.

Step 3 Obtain a sensitometric control strip for the colour duplicate negative process (for example a correctly processed Colour Intermediate control strip).

Step 4 Measure the integral densities of the steps of the control strip obtained in Step 3, to blue, green and red light, and plot the curves.

Step 5 Measure the gammas of the curves obtained in Step 4, and calculate the reciprocals of these gammas. For example if

DN (blue) = 1.02
DN (green) = 1.04
DN (red) = 0.93

then

$$\text{SP (blue)} = \frac{1}{1.02} = 0.98$$

$$\text{SP (green)} = \frac{1}{1.04} = 0.96$$

$$\text{SP (red)} = \frac{1}{0.93} = 1.07$$

These gamma values are best calculated as the parameter **best fit contrast** (BFC), although the parameter **average gradient** (AG) used for the process control of colour intermediate films can also be used but is less precise. These parameters are dealt with in Chapter 12 on control. (BFC values are calculated in preference to true gamma values for materials with rather uneven or 'shaky' D log *E* curves.) The values should be considered as temporary gamma values for the separation positives and they will be corrected later when the exact printing factors are determined.

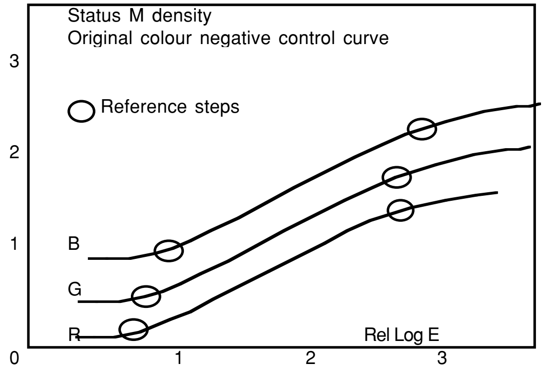

Figure 37.2 Eastman Colour Negative film: original colour negative control curve

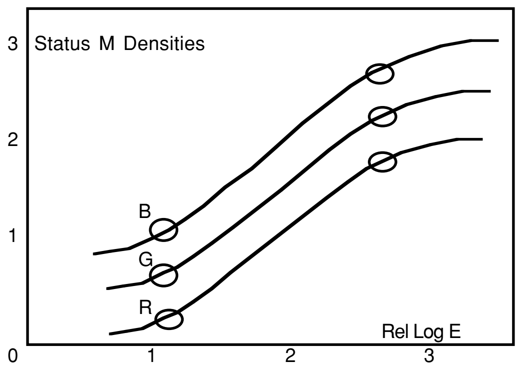

Figure 37.3 Eastman Colour Intermediate film with reference steps

37.4 PREPARATION OF MASTER POSITIVES

Step 1 Print the test loop onto the master positive material, for example Eastman Panchromatic Separation film, type 5235, through the appropriate filters (blue – Wratten 98 or Wratten 47B + 2B; green – Wratten 99 or Wratten 16 + 61; red – Wratten 70).

Step 2 Process the printed footage and control strips for a time estimated from the time–gamma curves to give the gamma values previously calculated.

Step 3 Measure the highest and lowest integral densities of the original picture negative to blue, green and red light and plot these values on the negative control curve (a 1 mm densitometer aperture will probably be necessary to measure the image, although a 3 mm is more repeatable for the measurement of control strips). The step numbers of the control strip for which the densities are closest to the picture densities can be marked on the control curve. These are reference points and the same steps should be measured and plotted on the control curves in each duplicating step. (See Figure 37.2.) This is quite straightforward when the original is a modern or even an early masked film. If the original is an unmasked film the steps that most closely correspond can be used or the steps on a piece of print film that most closely corresponds can be used instead.

Step 4 Plot the 'print-through' reference steps of each of the three master positives on their respective control curves.

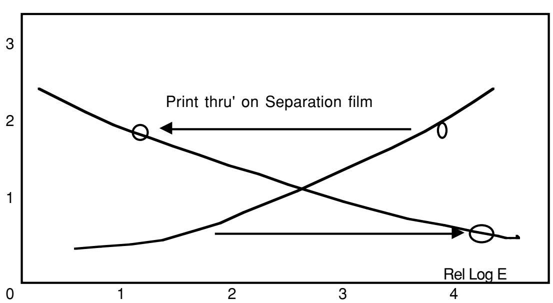

Figure 37.4 Blue control and print through curve on separation positive

Step 5 Adjust the printing levels until the picture density range is placed properly on the straight line region of the master positive control curves. If, for example, the picture density range plots too low on the control curve the exposure must be increased. Once this test process results in a set of printing levels that plot on the straight line of the master positive curves a set of separations can be made from the entire negative.

37.5 PREPARATION OF A SUBSEQUENT COLOUR DUPLICATE NEGATIVE

Step 1 Using a registering type step printer, print the blue, green and red master positive grey scale strips (print-through strips) onto the Eastman Colour Intermediate film, through the appropriate filters (blue – Wratten 98 or Wratten 2B + 47B; green – Wratten 99 or Wratten 16 + 61; red – Wratten 29).

Step 2 Expose a sensitometric control strip on the colour intermediate film using an exposure time that closely matches the printer exposure.

Step 3 Process the printed grey scale and control strip together through the recommended colour intermediate process.

Step 4 Measure and plot the integral colour densities of the control strip to blue, green and red light.

Step 5 Measure the integral colour densities of the reference steps of the grey scale and place these on the curve obtained in Step 4 above. (See Figure 37.3.)

Step 6 If the picture density range does not fall on the linear portion of the control curves, adjust the exposure level accordingly and repeat the procedure.

Step 7 Compare the picture density ranges (that is the difference in density from the high to the low steps in each colour) of the colour duplicate negative with those of the original negative. In all probability, the picture density ranges will not be the same, and this means that the separation positives have printing factors which must be taken into account. If the picture density range of the colour duplicate negative is **greater than that of the original negative** it will be necessary to use a master positive of lower gamma to correct the situation. If the picture density range of the colour duplicate negative is **less than that of the original negative**, a master positive of higher gamma will be needed. The printing factors PB, PG and PR can be determined by the relationship:

$$\text{PB, PG, or PR} = \frac{\text{(Density range of colour duplicate negative)}}{\text{(Density range of original negative)}}$$

The gamma values of the three separation positives are then corrected simply by multiplying by their corresponding printing factors.

It is at this stage that corrections for the differences due to using a different original material to that used in the initial test loop can be made. An early unmasked negative can be set up with a print control strip and the corrections made at this point when the density ranges of the original and the duplicate negative can be compared.

Step 8 Repeat Steps 1–5 applying the correction factors determined in Step 7 above to obtain the correct gammas and development times.

Step 9 Since printing exposure levels have been established, the picture original may now be duplicated. As a check on the processing conditions for the master positives, sensitometric control strips should be included in the footage. The density ranges of the colour duplicate negatives should now closely match those of the original negative.

37.6 NOTE ON SEPARATIONS FOR PRESERVATION

This procedure may seem time-consuming and tedious but it only need be set up fully once for each type of original material and needs to be checked again when the batch of black and white separation film or colour intermediate is changed. The differences in a well set up procedure and an empirically guessed one are considerable and the final print of a poorly set up system usually exhibits cross contrast.

Early negatives duplicated by this method are generally good, although a few did not have the same aim contrasts as the majority. Most early and later masked negatives including those of today all aimed for contrasts of about 0.60 and this makes the routine used for modern separation-making valid for all these stocks. However, some early colour negatives appear to have higher contrasts and these require special treatment as the modern print film is too high in contrast if a duplicate negative with a contrast of 1.0 is produced. The separation films are capable of operating at lower values, perhaps down to 0.7 and this allows lower contrast duplication overall. Inevitably this requires a great deal of trial and error.

37.7 BLACK AND WHITE SEPARATION METHOD FOR RESTORING COLOUR PRINTS

Eastman Panchromatic Separation film is also used to produce separation negatives from colour prints. The resulting negatives can be printed to make separation positives, then printed in register to make a new colour negative on Eastman Intermediate, as in the last stage of the procedure above.

This long and often difficult procedure is one way to make a presentable image from an old faded colour print or colour reversal.

Colour print	Contrast 1.5
3 separation negatives	Contrast 1.0
Prints from 3 separation negatives	Contrast 0.4
Eastman Intermediate negative	Contrast 1.0
Colour print film	Contrast 2.5
Final print	Contrast **1.5**

The procedure for preparing the separation negatives follows that of making separation positives from negatives but the contrast of the two black and white stages must be related so that the product of the two is one for each colour record. In the example above, the material used for making the separation negatives was Eastman Panchromatic Separation film which has natural gamma of about 1.0, and the prints from these are made on any Eastman Fine Grain Duplicating Panchromatic Negative film developed to a low gamma of 0.4. Other materials may need different contrast combinations and there are no standards for this procedure.

The filters used are usually Wratten 98, 99, and 70, but other 'wider cut' sets such as 47B, 61, 29 or the widest, 47B, 58, 25, produce less saturated final prints that may be more like the original images.

38

Notes on the schematic diagrams of Technicolor restoration routes

38.1 INTRODUCTION

Diagrams have been made to illustrate the various routes known to be used by laboratories and archives for the preparation of restoration prints from Technicolor elements. These also illustrate the contrast rule: the contrast of the overall reproduction of a photograph is a product of the individual contrasts of the film stocks used. The preferred overall contrast of any projected image is approximately 1.5.

38.2 TECHNICOLOR IMBIBITION PROCESSES

A Technicolor print is one made by the Technicolor Corporation. The various Technicolor processes began in 1917 and the last Technicolor imbibition print was made in Europe in about 1979, although there is a project in Technicolor, Los Angeles, to produce a new modern imbibition print system, which is still not yet operational (2000). The Technicolor Corporation gave its name to many different colour printing methods as the company's researchers searched for a commercial method of making colour prints for cinema release.

The method that is largely synonymous with the name Technicolor is a dye transfer printing process, virtually a graphic arts printing system, that began in 1935 and continued to the 1970s, sometimes called 'imbibition printing'. There were other, less well known, dye transfer processes for both still (Dye Transfer, Carbro and Vivex, for example) and for cine film (for example, in Japan).

The Technicolor process used initially a patented three-strip camera to produce three separation negatives. Sequential frame or single strip separation negatives were used from animation graphics for the same printing method. Cementing film elements together and other ideas were tried initially. In 1935 the three-colour imbibition system was introduced, together with a patented three-strip camera using a prism, a bipack (previously used for two-colour by many companies) and a single green record film. The red separation negative image was reversed in geometry from the other two and was corrected at the first printing stage to the matrix.

(The reversed geometry of the red image is not a reliable method of identifying Technicolor separations. Other less common two- and three-colour systems produced reversed separations.)

In the 1940s the 'monopack', a 35 mm Kodachrome film, also occasionally later 16 mm, was used as the camera film as a lightweight alternative to the three-strip camera. In the early 1950s colour negative film replaced three-strip and monopack as the camera material. In all instances where a colour film was used in place of the separation negatives a set of separations was made to create the matrices.

Also in the 1950s Kodak produced a panchromatic separation matrix film that allowed the positive matrices to be made directly from a colour negative just as they had been from the camera separation positives.

The Technicolor processes all required considerable handling of the many elements with the risk of damage at many points in the

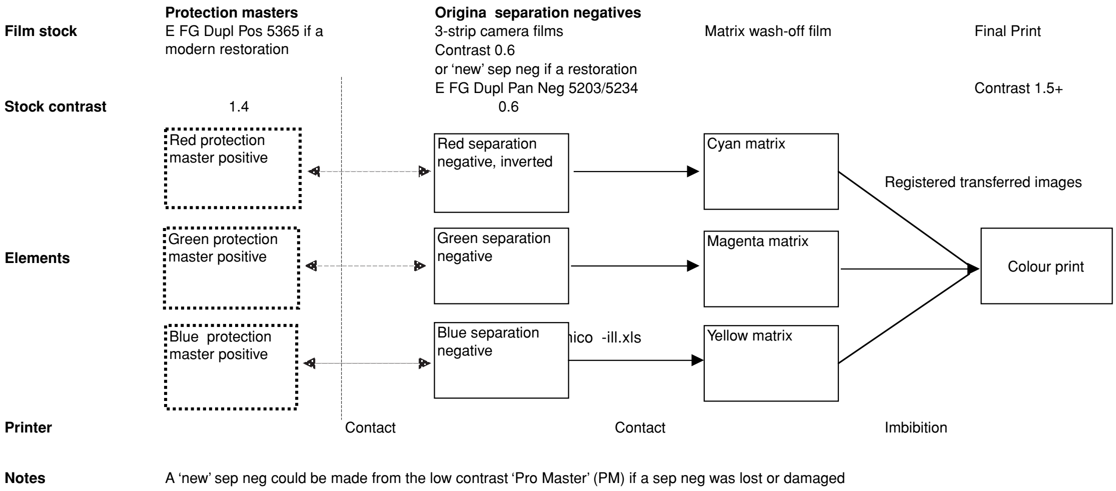

Figure 38.1 Diagram of Technicolor three-strip system route of about 1950

sequence, and positive 'protection masters' (called PMs, or 'pro-masters') were almost always made before printing and after negative cutting to allow new separation negatives to be made in the case of damage. These were black and white film prints of the separation negatives, usually on a film stock of gamma 1.66, specially made as an insurance against damage to the separation negatives. Pro-masters are therefore positive and the red separation is the same geometry as the other two colours (i.e. is reversed in printing).

The contrast and method of making protection masters did change over the years as the different camera originals changed. The camera original materials were either negative film, colour or black and white with a development gamma of 0.60 or were various reversal originals like Kodachrome with a contrast in excess of 1.0, and generally the positive protection masters were made to have overall reproduction contrasts of 1.0.

Technicolor dyes changed as the years went by just as the technology of printing changed and some periods saw complex mixtures of dyes used as the primaries. These became single dyes in later years.

Technicolor is often felt to have a single visual print character that is recognizable, but in reality, there were many different appearances, with a relatively high contrast and saturation and a restricted but bright colour range in common.

38.3 RESTORED PRINTS FROM TECHNICOLOR SEPARATION NEGATIVES AND POSITIVES

38.3.1 Common methods

Laboratories that make colour restoration or access prints from separation negatives suffer from several uncertainties. The technical literature contains a number of recommendations for restoration routes and these are sometimes in conflict with one another. Presumably the variation is linked to the variation in preferences for the final print result.

Sometimes one separation element is lost. In some cases it is possible to 'reconstruct' an alternative from the remaining separations. The results will never be correct.

Sometimes the green separation negative was used to produce black and white prints and therefore it is quite common to find that this element is well used and more scratched or damaged than the other two.

As with most colour archive film restoration, it is necessary to use whatever film stocks are available, in a non-standard manner, to obtain a restored print. The contrast rule is invaluable as a simple guide to planning the route, but is little understood in archives. Ensuring that the film layers track well when non-standard processing or when flashing is used is essential and routine sensitometry is essential. The LAD method is adequate for most standard

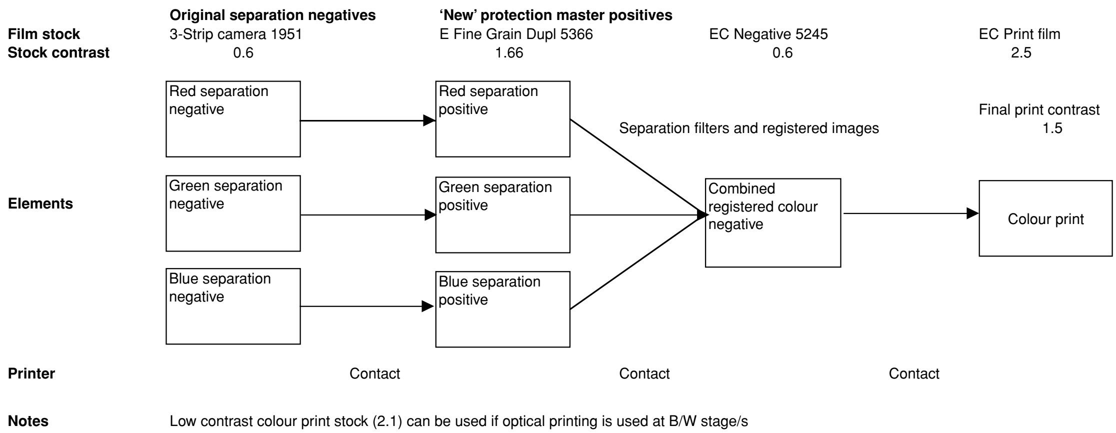

Figure 38.2 Technicolor restoration method 1 (FIAF recommendation using Eastman Colour Negative film, contact printing from separation negatives)

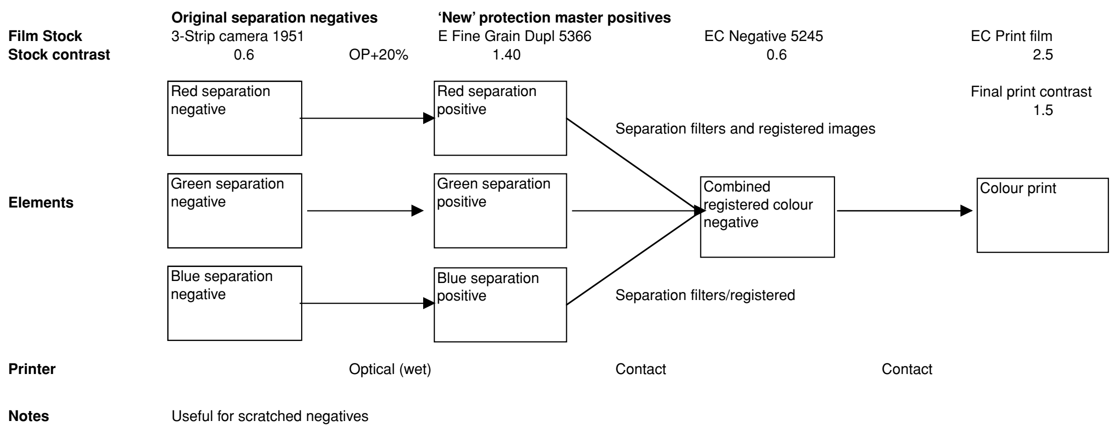

Figure 38.3 Technicolor restoration method 2 (FIAF recommendation using Eastman Colour Negative film, optical printing)

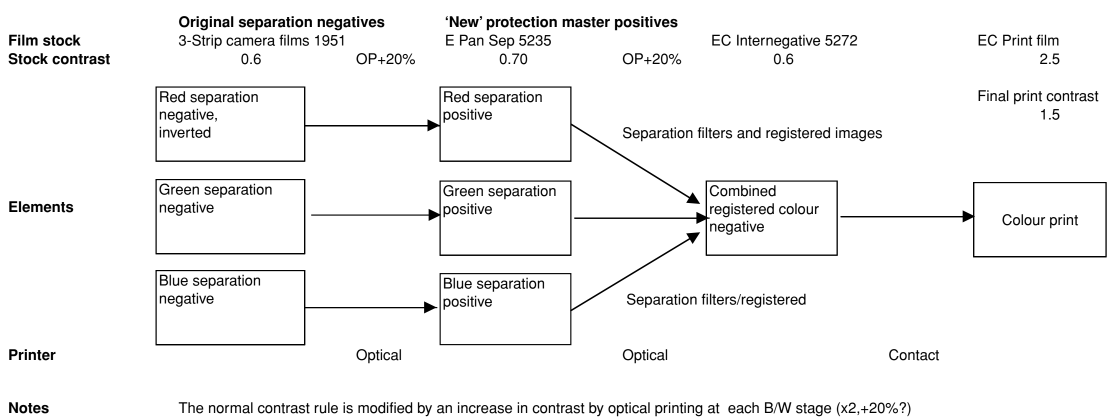

Figure 38.4 Technicolor restoration method 3 (using Eastman Colour Internegative film)

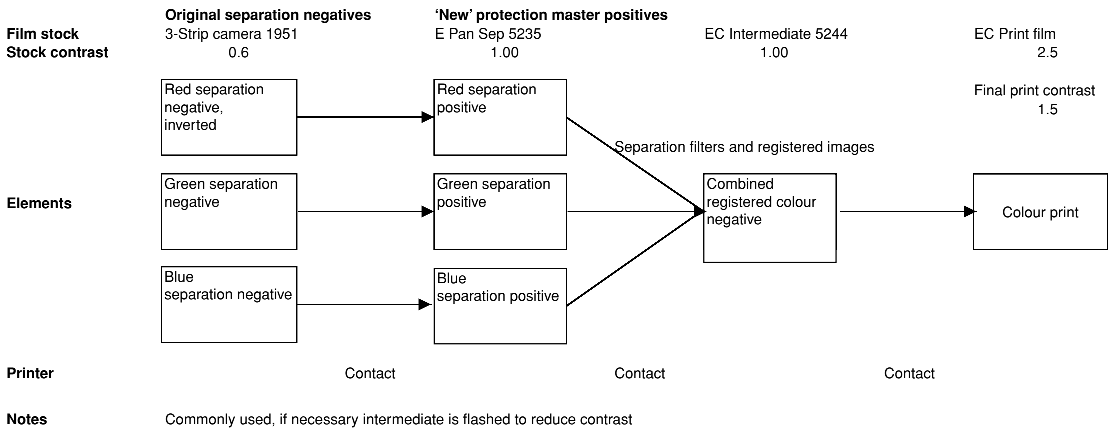

Figure 38.5 Technicolor restoration method 4 (using Eastman Colour Intermediate film)

duplication methods but the 'full curve' or 'two point' system of Kinsey and Gale is necessary if the method is not routine.

Figures 38.2–38.5 show just some of the most widely used and well-known recommended routes. In these diagrams the contrasts of the stocks and, where relevant, the printing method are shown. These values demonstrate that the contrast rule can be applied and that the usual preferred final overall reproduction contrast of 1.5 can be achieved in every case. Optical printing of black and white film increases the contrast of the result by up to 20%. This effect does not occur with contact printing and colour film contrast increases are usually too small to take into account.

Eastman Colour Internegative and Intermediate contrast reduction is best carried out by selective layer flashing *and* 'pull processing' to achieve a consistent result, but the contrast of these products is not easy to alter in a controlled manner.

38.3.2 Preferred appearances

Different clients prefer different visual appearances in the finished print. Sometimes the differences are slight but sometimes a client will reject a print that is similar in appearance to an original Technicolor imbibition print, preferring a lower contrast result more like a modern Eastman Colour Print film from a modern negative. Some laboratories have clients that state that they do not want an image that looks like the original Technicolor print!

Original Technicolor prints do not fit the requirements of television well, and inexperienced television engineers often reject both original and restored Technicolor images as outside the specified modern EBU quality guidelines. (German TV companies are well known for this inflexibility.) The optical effects, fades and dissolves, for example, were for a long period made by duplicating an entire scene, or pairs of scenes. These optical effects are of lower image quality than the other scenes. The images of the body of a film are two, three or four generations from the original negative, but optical effects required more generations (sometimes as many as six or seven). Some clients define the route by which the restored print must be made and this may not enable the laboratory to provide the optimum result.

38.3.3 Direct printing

A method of producing a very good quality print is to print the original three-strip negatives directly onto Colour Print film through separation negatives. Some small contrast control can be made by flashing the print film if necessary but little is usually needed since the combination of contrasts is usually correct. This method is rarely used as no duplicate negative is made, so that it is really only of use to produce one print.

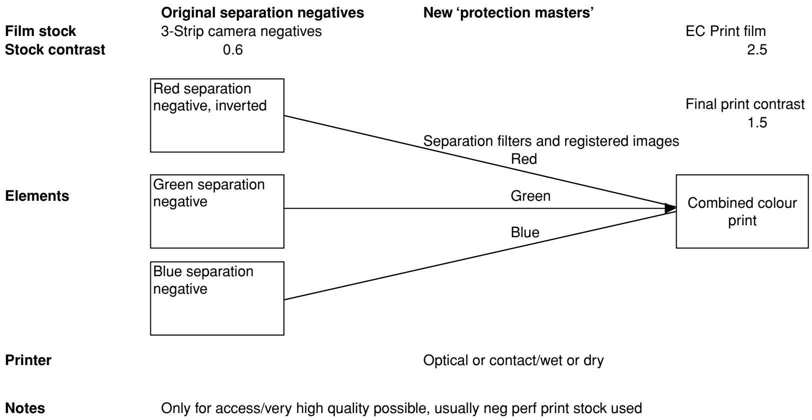

Figure 38.6 Technicolor restoration method 5 – direct to print method (FIAF recommendation – for access only)

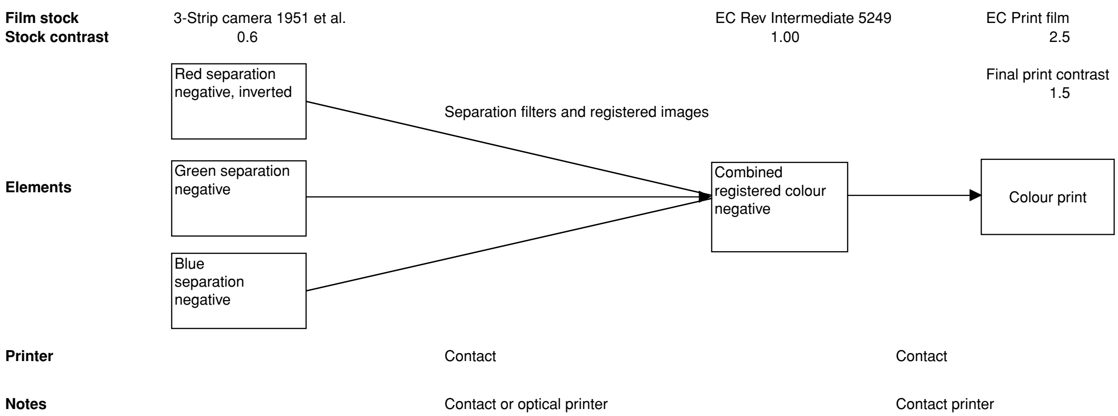

Figure 38.7 Technicolor restoration obsolete method using Eastman Reversal Intermediate

38.3.4 Reversal Intermediate film

Many restored prints must be made from existing elements provided by the client, and which were made *since* the original separations were produced. Colour Reversal Intermediates, duplicate negatives on Eastman (or Fuji) Colour Intermediate films of various vintages all produce different print results outside the control of the laboratory, but which are frequently criticized as not producing the 'required' quality print.

Technicolor themselves made combined negatives on Colour Reversal Intermediate film from separations. These produce prints that look nothing like Technicolor; more like desaturated Eastman, with poor colour tracking and uneven densities. This obsolete film stock should be avoided if possible by making a new restoration from earlier elements.

38.3.5 Restorations from protection masters

Technicolor companies produced their own protection master positives from original camera separations as a means of recreating a new separation negative in the event of damage or loss. The aim contrast varied but generally they were intended to have an overall reproduction contrast of 1.00. However, protection masters are not consistent, and prints made from them rarely, if ever, equal the print quality of prints from original camera separations, but this is not appreciated by clients in general.

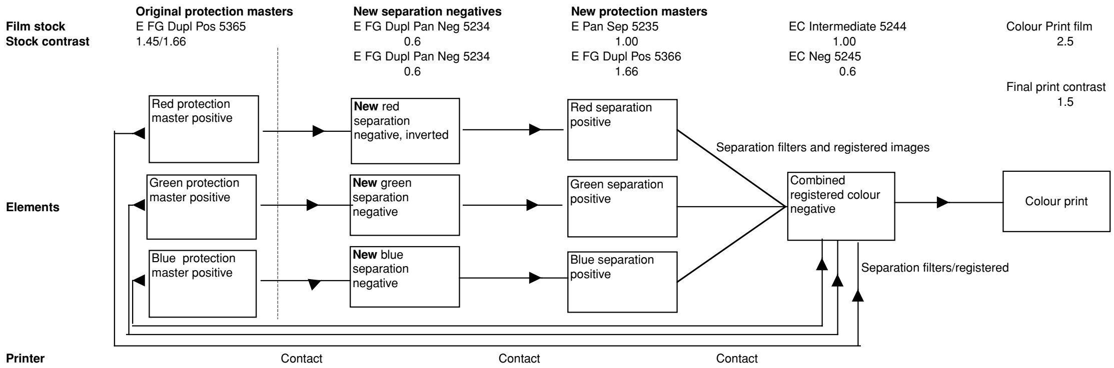

Figure 38.8 Technicolor three-strip restored prints from new or original protection masters using Colour Negative or Colour Intermediate films

Some archives have extensive collections of these protection masters which may never have been used to produce a print. On the other hand, PMs have no joins, and may be in more or less virgin condition.

Separation positives were (occasionally still are) made as protection masters from other colour original films, especially from integral colour negatives (for example on Pan Separation Film). The procedure, contrasts and the film stocks used were (or are) different from the procedure for producing Technicolor protection masters, and the resulting restored prints are visually different, but this is rarely recognized by clients.

39

Notes on restoring subtractive two-colour process prints

39.1 HISTORICAL

Two-colour subtractive print systems were in use from about 1915 to about 1950, and companies in many countries produced and patented their own versions.

Two separation negatives are produced in a single camera exposing either a 'bipack', two films emulsion-to-emulsion in a single gate, or in a camera with a beam splitter and two film elements. The separations are made with a red–orange and a cyan–green complementary pair of filters, or relied on the different sensitivity of the films (in the case of the bipack) to produce a similar result. Thus complementary records were generated covering the entire visible spectrum.

The print was a single film base with red–orange and cyan–green positive images each made from a separation negative. The images were on either side of the film base, (e.g. Cinecolor) or on the same side (e.g. Dascolour, early Trucolor). The dyes were produced from the silver images by dye transfer, by chromagenic development, even by a form of litho printing, but most frequently by toning, using metallic and mordant dye techniques developed for toned silent films.

The processes were highly successful until three-colour Technicolor in 1936, and even then hung on until Gevaert and Eastman Colour Negative films in 1947–50.

From about 1930 Eastman, Agfa, Gevaert, DuPont (who called their bipack 'Rainbow Negative' and later DuPack) all made 'bipack' films for camera use. One negative geometry was reversed as the films were usually exposed emulsion-to-emulsion, but almost any camera could be simply modified to supply and take up to two rolls of film. These same manufacturers also made double-coated print films, usually using their standard black and white emulsion coated on both sides of the nitrate support. These films were called Duplex or Duplicoat (DuPont) or Duplitized (Eastman) etc.

The sound tracks, where present, are usually variable density and a bright Prussian Blue, more rarely silver coated with a shiny cellulose nitrate lacquer.

Two-colour print technology failed to make the jump to three-colour, although several complicated three-colour versions were tried. The last British two-colour was Cinecolor (Slough, Bucks) and the last three-colour of this type was SuperCinecolor (processed as a joint venture by Cinecolor, Gevaert and Studio Film Laboratories in 1950). Early Technicolor prints were two-colour, either by cementing two films together or by two-dye transfer images onto 'blank' film stock. Technichrome included a complex method of deriving a three-colour print from two separation films.

Only Harriscolor (USA 1929+), Kelleycolor (USA), Polychrome and Kodachrome (USA, 1920) and Fox Natural Color (1924) used beamsplitter cameras, and prints from these systems are very rare indeed. All others used commercial bipack films pairs that were not unique to the print process.

(The terms bi-pack and monopack have been confused for many years, since they are used as loose terms for a number of different still and motion picture systems. Technicolor called Kodachrome 'Monopack' when they used it as a camera film in 1945, and Ilford produced a 'bipack', producing three separation negatives from two films, for still use, which they called Monopack!)

39.2 IDENTIFYING THE PROCESS

Identifying the colour system is essential to produce an authentic restoration as the dyes varied widely. The two colours were intended to be complementary but this can cover a wide range of colour combinations.

Blues are poor, probably as much due to the dyes darkening with time, reds are strong and saturated, but some results are extremely pleasant. Sharpness was usually poor on double-sided print films.

Identifying the system can *only* be done from a print and is partly by identifying geometry and layer arrangement and by identifying the dyes and sound tracks.

Prussian Blue is a common cyan blue used in Dascolour, Harriscolor, early Kelleycolor ('Prizma'), Colorfilm, Fullcolor, early Cinecolor, Kodachrome 1920ish, Multicolor and Magnacolor(?). The orange dye was occasionally uranium ferrocyanide but more usually a mordant dye mixture. Some processes used chromagenic development.

The density of any pure dye areas must be measured on Status A.

Identifying the film stock manufacturer may help, or may not. Most US film stock manufacturers made a double-coated stock for these processes.

Some two-colour, perhaps all, was printed on a yellow film base or the emulsion was tinted to produce a subjectively better result.

The best general source of references and other data is A. Cornwell-Clyne's *Colour Cinematography* (1951), and R. Ryan's *A History of Motion Picture Colour Technology* (1977). Most US systems were well described in *SMPE Journals.*

39.3 MAKING A RESTORED PRINT FROM SEPARATION NEGATIVES

If only separations exist it is rarely possible to tell from them which print system would have been used, and different print systems could have been used with the same pair of negatives at different times.

If both separations and a print exist a close match to the original print can be made from the separations as follows:

1. Identify which separation is which. As with any set of separation negatives this is either by trial and error or a knowledge of the geometry of the process. Bipacks were exposed with the films emulsion-to-emulsion and therefore one image will be the reverse of the other. One film must therefore always be reversed in its subsequent handling.
2. Prepare test exposures on Eastman Colour Print Film 5386 to achieve a densitometric (and visual) match with the primary colours using short lengths of the separation negatives. Usually areas of pure dye can be seen in splashes, outside the perforations, or at reel ends, which can be used as colour patches. Either additive or subtractive lamphouses can be used.
3. Make a register print on Eastman Colour Print Film 5386 by two separate passes, one from the blue/green separation the second from the orange/red, producing the B/G primary from the O/R separation and so on.
4. Grade the final print by varying the total exposure of the two separations (not by varying the colours produced as primaries) Neutral density filters are the best method, but scene-by-scene grading cannot easily be done this way, and some printer light adjustments may be needed.

[**Editor's Note:** I have only carried out this procedure once, as separations are rare (or overlooked); the occasion on which I have used this method was when a client said he had lost a separation negative! However, the can was labelled with a Cinecolor label, the film was Eastman bipack and one negative geometry was reversed. P.R.]

39.4 MAKING A RESTORED PRINT FROM AN ORIGINAL PRINT

Most two-colour materials only exist, at least in Europe, as a release print.

Step 1 Carry out the identification process as above, and identify the dyes if possible. Measure the Status A densities of the dyes.

Step 2 Make two separation negatives from the print. Filters we have used for this are Wratten 16 (orange) and Wratten 44 (cyan), and also the narrower cut pair Wratten 22 and Wratten 45. There are increases in saturation in the final print with the latter, but they reduce exposure considerably. Time–gamma curves are needed to produce matching gammas of 0.6 for both separations. (We have also tried using an additive lamphouse to achieve the separation exposure wavelengths. This was successful but only used for a test.)

Step 3 The print is made as for the restoration above from original separation negatives, which as far as is known were all made to an approximate (natural) gamma of about 0.6. We did find some earlier films with much higher contrasts and have needed separation gammas as low as 0.4, especially where optical printing was used from black and white elements.

39.5 CHOOSING THE COLOURS OF THE TWO PRIMARIES FOR PRINTS

The following dyes are known to have been used for two-colour prints.

39.5.1 Cyan/blue primaries – Prussian Blue/Iron Tone Blue/iron blue tone/ferric ferrocyanide

This is the classic Prussian Blue formed by the action of ferric chloride and oxalic acid on metallic silver. All the processes we have seen described suggest the silver was ‘fixed out’, and sometimes ‘bleached out’ with the far more effective ferricyanide bleach rather than fixer. Prussian Blue is more stable than many chromagenic cyan dyes, but darkens and desaturates in time. All two-colour films using this primary should be restored with a colour that matches ‘fixed out Prussian Blue’.

In Dascolour, potassium ferricyanide bleach removed all silver. This was probably a very saturated blue, but we have not seen this. It was a single-sided emulsion process, probably one separation colour originally printed through support.

In Harriscolor, ‘Prizma’ Kelleycolor, Colorfilm, Fullcolor, Cinecolor (early version) and Multicolor various formulations resulted in Prussian Blue, with various levels of ‘fixing out’, probably with various levels of effectiveness. Kelleycolor went through many generations using a wide range of dyes, including a vanadium salt, although this may have been part of an elaborate mordant dye tone process.

39.5.2 Cyan/blue primaries – mordant cyan/blue dyes

Few patents list the precise dyes used. The only well-documented cyan/blue mordant dyes are for polychromide, a mixture of Malachite Green and Helio Saffranine. The later Cinecolor used a mordanted cyan/blue (unknown?).

(Cinecolor, the longest running process (1931? to 1950), and the most widely used, especially for B Westerns, went through many technical changes.)

39.5.3 Orange/red primaries

Harriscolor and Multicolor used uranium toner solution and the resulting metallic dye included or consisted of uranium ferricyanide.

With the exception of the dye transfer dyes and chromagenic dyes listed below, all others were mordanted dyes. The mordants was usually silver iodide. The only documented dye we have found so far was for Cinecolor – a mixture of Auramine O and Fuchsin.

39.5.4 Chromagenic dyes

Trucolor used chromagenic dyes based on ‘CD1’, di-ethyl p-phenylene diamine (for both primaries).

39.5.5 Dye transfer dyes

These were used for Kodachrome, 1918, and Technichrome, but we have no data on either dye or colour.

39.6 SOUND

Most two-colour prints had Prussian Blue sound tracks exposed from a separate sound negative but onto the cyan/blue image emulsion and developed with it. In some cases (e.g. some Cinecolor) the silver seems to be retained by lacquering before the 'fix out/bleach out' stage.

Some (e.g. Trucolor) have pure silver sound tracks but no data is known as to how this was achieved, probably by some form of redevelopment.

Restoration of the sound is straightforward. It can be re-recorded and a new track produced which is printed at the same time as one of the printing passes.

39.7 SIMULATION OF A TINT

The yellow or pale orange tint present in some or most two-colour prints can be simulated by a flash print pass (with no image in the gate) solely to 'tint' the image area. This is identical to the tint pass in the Desmetcolor method.

The origins of this tint can be related to the Ive's Polychrome process of about 1918. Ive's two-colour still process used cyan/blue and orange/red and then, since the result produced a poor, rather cold, neutral scale, the whole print was tinted yellow. The grey scale became neutral and the skin tones warmer, but still acceptable. Ive's called it a 'two-and-a-half colour process'. We have not found any other references to it than this, although nearly all two-colour prints are tinted amber or yellow. Also many early stencilled prints are also tinted overall yellow, which increased the subjective effect.

39.8 PRESERVATION OF TWO-COLOUR SYSTEMS

Preservation of the separation images can be undertaken by making positive protection masters in exactly the same manner as that used for preparing Technicolor protection masters. Whenever a negative is required for a restored print a new silver separation negative can be made. Contrasts can be treated in the same way as Technicolor, as most original separations were about gamma 0.6.

Where only the print exists the new separation negatives made from the print will become the primary preservation material.

40

Sound restoration case studies

40.1 'O DE CONDUITE', AN EXAMPLE OF SOUND RESTORATION

The restoration of this film sound track, directed by Jean Vigo in 1933, is an example of the different processes, and the technical and ethical problems confronting a restorer.

The original negative was damp, and had a variable area sound track with a variable width. We received, as a reference copy, a very bad print in which the sound was uncompleted and was no help. The film had obviously been produced under poor technical conditions. The sound track had not been mixed, and was full of blanks, splices and shifts of synchronism (probably due to incorrect recording). Many parts of the sound were unrecoverable or missing.

In order to print a positive from the negative without knowing the necessary cross-modulation compensation several test prints were made at different printer light settings, adjusting as best as we could the lateral position of the track to get the most of the variable width. We eventually succeeded in replacing the poor reference copy, after many searches, with a fairly good one from a foreign archive.

The work of restoration was long and complex, with many difficulties. The broad band noise was particularly difficult to clean because the No Noise system (a digital sound restoration software) was not used in France at that time, and the white areas of the sound track were particularly noisy (and affected by a cyclic broad band noise). Wherever the original was water damaged, the sound was generally completely unusable.

We had several meetings with the rights owners in order to establish which blanks and missing parts in the sound were intentional. We had to distinguish between technical limitations that were not planned by the author, and

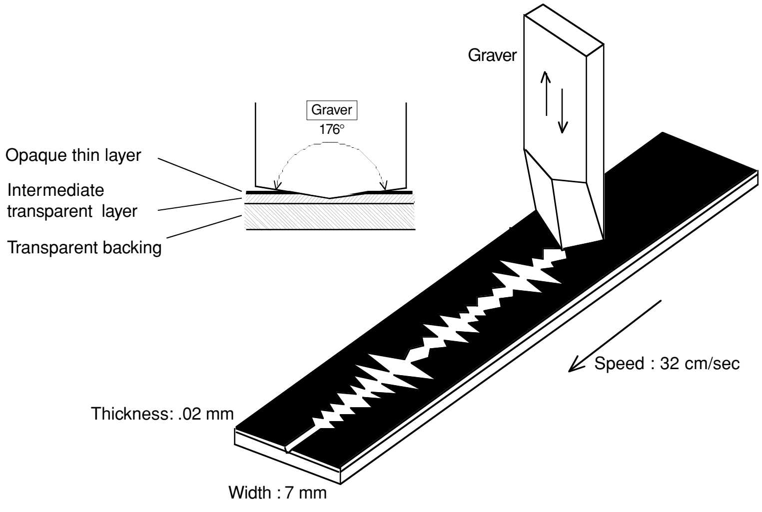

Figure 40.1 The Philips–Miller process

specific limitations that were intentional. In this way we decided which gaps needed to be filled, and with what. Part of a scene in which the sound was completely missing was reconstructed by using short extracts from the existing sound edited to fit the image. Some music was unusable both in the negative and the reference print and we had to replace it by a recording from a 78 rpm disc of the same period whose sound quality was actually far better.

Having two reference prints was far better than one, as the unusable parts were different in each, and so sections of the 2nd print sound track were used to make inserts into the track from the 1st.

The last operation was carried out in a mixing studio in order to create a uniform dynamic balance that respects the modern settings of projection in a modern cinema. The tonality of the sound was modified to fit the new screening conditions. The links between original sound elements and the reconstructed ones were modified by appropriate mixing so that they were imperceptible. This last process was the requirement of the right owners, and is not always a specific requirement.

40.2 REPRODUCING SOUND FROM EARLY UNIQUE TRACKS

In order to be able to play out some archive sound tracks it is necessary to design and build a special playback machine, if one does not still exist in working order. Sometimes the only mechanisms available are in such a delicate state that damage to the film or the apparatus might occur if re-used.

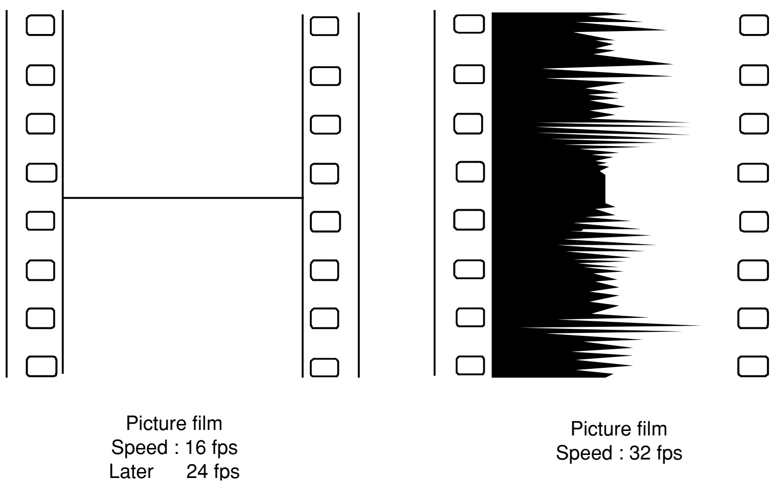

Figure 40.2 Petersen and Poulsen Sound System (Gaumont Petersen and Poulsen – GPP – in France)

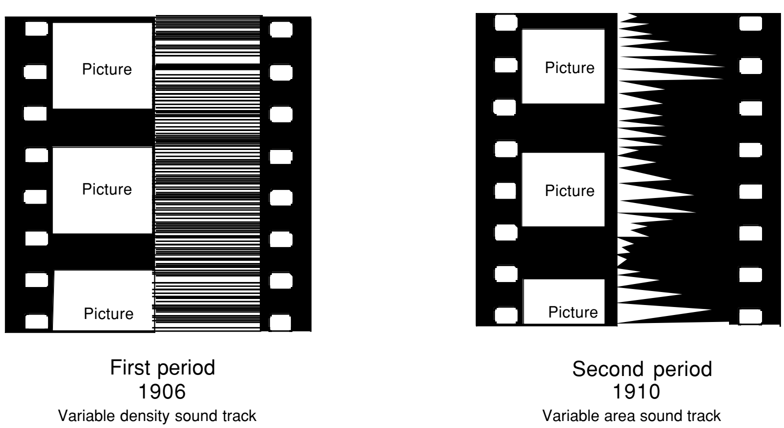

Figure 40.3 Lauste sound systems, variable density and variable area

The film transport system has to be adapted for each process and the reading is generally done by a solar cell and with laser scanning.

One example is the the Philips–Miller process which was derived from both disc recording and optical recording. It was, before the coming of magnetic recording, the sound recorder that gave the best mechanical and electro-acoustic performances.

Other examples of unique 35 mm systems that did not have a sound track in the conventional position between image and perforations are Peterson and Poulsen, in which the image and sound films are separate, and the various versions of Lauste. Triergon (1922) was 42 mm film, the extra 7 mm outside the perforations of 35 mm comprise the track area.

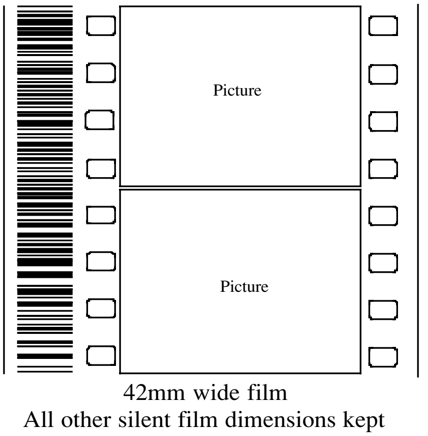

Figure 40.4 Triergon Sound film (1922)

Glossary of terms

The following terms are all widely used throughout the film laboratory and archive world wherever English is used as the language of communication, and generally the definitions are those used in this book. Many authors contributed to the book, and most were from non-English speaking countries. The initial translations were carried out by the authors themselves, with help sometimes from specialist translators, and the Editor has attempted to unify the technical terms. This has not been easy.

The FIAF Preservation Commission has published a short definition of some of the terms, and where a FIAF definition exists this is generally used in this publication. However, other definitions have been added by the Editor. These additional terms, which make up the majority, are all used throughout the film laboratory industry, or in archives today, or are terms used in the past but generally lost to the industry now. Wherever possible the glossary definitions come from the British Kinematograph Sound and Television Society glossary.

In film laboratory work there are some marked differences between the terms used in the USA and those used in areas influenced by the British laboratories. The best example is **grading** and **timing**, the first being the British term, and the second being the American term for the same procedure. The British term is used throughout the text, as it is familiar to all the authors and the editor. However, a number of important American terms are included in this glossary where they differ from the British.

A complicating factor in film terminology is the variation in usage and terms between different laboratories throughout the English-speaking world. Many laboratories, particularly in London, operated for a great many years with the same staff, and through many important technical changes, some of which they themselves brought about. It was inevitable that local terms became used and some of these spread to their clients, the film makers, and to editors.

A good example of this is the British Pathé Laboratory which existed from the early 1920s to 1970 and in that time introduced many specialist newsreel techniques. Local names were invented and while some of these filtered out to the world at large many were entirely 'in house' terms. Others were terms in common use in the industry but used in a different context by Pathé technicians! A good example was the Pathé technicians' use of the term 'lavender', which was Kodak's 1930's term for a duplicating material coated on a pale blue coloured base. Pathé may never have actually used this stock and certainly preferred to use conventional print film for duplicating, processed to a lower contrast instead (because duplicating stocks were considerably more expensive than print films). Nevertheless, their technicians continued to call *any* duplicate negative they made a 'lavender' for the next 30 years. This makes the process of reviewing the literature and paperwork of a long-established company difficult, and the labels on the cans may seem at odds with the contents. In 1992, when a large proportion of the British Pathé material was transferred to digital video tape, a special glossary had to be written to explain about 25 unique or unconventionally used terms to the technicians involved.

Many other laboratories, especially Technicolor, had similar local terms, and this occurred in France and Italy and probably elsewhere.

The stock manufacturers did their best to rationalize terms and to create uniform ones, but sometimes introduced even greater diversity and in some cases just added to the confusion. A good example of this was the change in name by Eastman Kodak of one of their film stocks from Colour Internegative to Colour Intermediate in the early 1950s. To this day, film makers, and unfortunately some laboratory staff, confuse these two, and therefore confuse the terms **internegative**, **duplicate** and **intermediate**. A black and white duplicate negative is called a **duplicate negative**, while a colour duplicate negative is still frequently called an **internegative**.

Sometimes even today laboratory technicians contribute to these problems – largely still due to the insularity of the companies. These confusions have become less since the publication of the BKSTS and SMPTE glossaries but great care needs to be taken with old documentation, especially if it is a can label or technician's notes in a can with a reel of film. It is better not to assume a modern usage (or any standard usage), especially for such terms as **duplicate**, **slash print**, **reversal**, **copy**, **mute**, **internegative** or **interpositive**.

A further area of confusion is the tendency to jargon or slang usage that describes an **element** in terms of the type of film stock used to make it. The most common occurrence of this form is the use of the term **fine grain**. Eastman Fine Grain films are a category of monochrome duplicating films that are used for making duplicate positive, duplicate negatives and printing, and in some cases, whose contrast is controllable by processing within quite broad limits. It is still common for laboratory technicians to use the term 'a fine grain' when they mean a duplicate negative or positive made on an Eastman Fine Grain film. For some years the term 'fine grain' was used in price lists to mean duplicate elements of one sort or another even when the film stock used was not Eastman Fine Grain but some other. Just to confuse the terms still further, Kodak still call their normal print film Eastman Fine Grain Print film. 'Fine grain' is simply a promotional term.

From this it can be seen that motion picture film terminology is a major pitfall for the unwary, and it is recommended that, in all discussions about elements and duplication in particular, one should be continually conscious of possible misunderstandings. The problems diminish as standard terms become accepted, but always judge the contents of an old can by the film, not the label or the paperwork inside it.

A and B CUTTING	A method of assembling film in two rolls (or more) to permit special effects or checkerboard printing (16 mm)
A and B PRINTING	Printing two (or more) rolls of film onto a single print film to produce special effects or hide splices (16 mm)
A and B ROLLS (and so on)	The rolls of cut negative used for multiroll printing, could be any number
A and B WINDINGS	The two forms, or symmetries, of winding used for 16 mm or other single side perforated film
A or B TYPE	Terms used to identify emulsion position in 16 mm projection, type A is emulsion to lens, Type B is emulsion to lamp
ACADEMY	The Academy of Motion Picture Arts and Sciences (USA)
ACADEMY APERTURE	Aperture of a 35 mm motion picture camera or projector with dimension specified by the Academy
ACADEMY GATE	Projector gate used to define an Academy aperture
ACADEMY LEADER	Leader (*see*) on a film print with synchronizing marks and information designed by the Academy
ACCESS	Procedure of locating and supplying archive film for display outside the archive
ACETATE	Cellulose acetate, loose term for cellulose acetate film base

ACID DYES	Dyes used for tinting film emulsions in aqueous solution, in which the colour is in the negative ion (anion)
ACUTANCE	Term used to describe the edge definition at a density change (on a film image)
ACVL	Association of Cinema and Video Laboratories (USA)
ADDITIVE COLOUR	Process of colour synthesis using red, green and blue light, requiring the three images to be projected or viewed in register
ADVANCE	The separation between a point on the film sound track and the corresponding picture image
AERIAL IMAGE	An optical virtual image in space rather than a real image on a screen
ANAGLYPH	Stereoscopic projection using left and right eye images indifferent colours; viewed by complimentary filters
ANALYSER	Video display equipment for grading that produces an image that simulates a print. (USA Analyzer)
ANALYSIS	Process of separately producing records of red, green and blue light corresponding to these components in a scene
ANAMORPHIC (1)	A cinematographic image with lateral compression produced by an amorphic lens
ANAMORPHIC (2)	An optical system with different vertical and horizontal magnifications
ANILINE DYES	Dye chemicals produced from aniline, invented originally from coal in the nineteenth century
ANIMATION	Frame by frame exposure of images that simulate motion
ANSWER PRINT	The first print of a film submitted for approval by a laboratory
ANTI-HALATION	Coating or layer on film to reduce halation
APERTURE (1)	The opening of an optical lens system that controls the light transmitted
APERTURE (2)	The opening of a camera, printer or projector that defines the image shape and size
AR	Aspect ratio (acr)
ARCHIVAL	Archival films are those an archive has chosen to preserve
ARCHIVE (FILM)	An organization for preserving films
ARTIFICIAL LIGHT	Light generated by any light source except the sun
ASA	American Standards Association, also the film speed system described by the ASA
ASC	American Society of Cinematographers
ASCII	American Standard Code for Information Interchange, the standard computer character code
ASPECT RATIO	Proportion of width to height (height as unity) of a film image picture
ASSEMBLER	A technician who prepares film for a laboratory process like printing or grading
AUDIO	Sound – used to describe any sound recording or playing equipment, or the entire chain
AUTO-OPTICAL	A method of printing dissolve effects from a single roll of negative film on an automatic optical printer
AUTO-SELECTIVE PRINTING	Auto-optical (syn) US term
AZIMUTH (1)	The angle between the slit of a photographic sound head and the film path direction
AZIMUTH (2)	The angle between the magnetic head and the film or tape path direction (video tape)

BACK FOCUS	Distance from a lens to its image plane
BACK PROJECTION	Image projection onto the rear of a translucent screen, also a special effect using the technique
BACKING (1)	Anti-halation backing, or any coating on the back or base of a film
BACKING (2)	A black (usually remjet) coating applied to the film base to reduce halation
BAFTA	British Academy of Film and Television Arts
BALANCE	Term used to describe the 'neutrality' of a colour film or TV image
BALANCE STRIPE	Magnetic stripe applied to a film on the opposite edge of a film with a magnetic sound track to ensure uniform winding
BASE	The transparent support on which the photographic emulsion of a film is coated
BASE SIDE	Scratch on the base or cell (celluloid) side of film = cell scratch
BASIC DYES	Dyes used for toning film using mordant dyeing technique, in which the colour reside in the positive ion (cation)
BATCH NUMBER	Coating batch code for photographic film
BBC	British Broadcasting Corporation
BEAM SPLITTER	Camera or printer device for separating light or images into two or three beams (usually R, G and B)
BELL & HOWELL TAPE	Punched paper printer tape (*see*) with a non-standard punched tape code
BIDIRECTIONAL (PRINTER)	Film printer capable of printing both forwards and backwards
BILATERAL SOUND TRACK	Photographic sound track with a modulation symmetrical about its centre axis
BILATERAL SOUND TRACK, SINGLE	One single bilateral sound track image
BILATERAL SOUND TRACK, DOUBLE	Two parallel bilateral sound tracks
BILATERAL SOUND TRACK, TRIPLE	Three parallel bilateral sound tracks
BINDER	The material carrying the metallic oxides in a magnetic coating
BIPACK	Two separate sensitized films running in contact in a camera, printer or other device, intending to be exposed one through the other. Also DU-PACK
BKS	British Cinematographer Society, old title before change to BKSTS
BKSTS	British Cinematographer, Sound and Television Society
BLACK	Incapable of reflecting or transmitting any visible light – a subjective term
BLACK AND WHITE	Loose term for silver image film, as distinct from colour film
BLEACH (1)	To remove or decolorize the silver image, usually by conversion back to silver salts
BLEACH (2)	To remove the visible colour of a dye
BLEACH (3)	A solution used to bleach a film image
BLIP	Loose term for a short sound on an optical or magnetic track to be synchronized with a sync mark on a film
BLOOP	A triangular patch (or a punched hole) used to avoid the noise of a splice in an optical sound track
BLOOPING	The act of blooping, specially using blooping ink
BLOOPING INK	A dense, fast drying dye for use in place of a bloop
BLOW-UP	Enlargement of a film image
BLUE	One of the three additive primaries

BLUE BACKING SHOT	Action shot against a blue background, for combination printing by Chromakey or Travelling Matte
BREAK-DOWN	Separation of a roll of camera original negative film into its separate scenes
BRIGHTNESS	The luminance of a surface emitting or reflecting light, candelas/m^2
BRITTLENESS	Subjective term for fragility and tendency to break of a film, a result of loss of plasticizer or water
BS	British Standard, unit of photographic speed in BS units
BSI	British Standards Institute
BUCKLE	Subjective term for severe cockle of film caused by local uneven shrinkage
BURN-IN (1)	Producing white titles on already exposed film by overexposure
BURN-IN (2)	The addition of time code numerals to a video tape
BUTT SPLICE	Film join where ends are not overlapped, but butted, usually taped
BUTT WELD	Film join in polyester where ends are butted together and heat welded
BUZZ TRACK (1)	A test film to determine whether the scanning slit of a projector is correctly aligned
BUZZ TRACK (2)	A sound track recorded with local sounds to fill in a gap in a sound track
CAMERA	Device to form an image with a lens onto a film
CAMERA LOG	Record sheet with details of scenes shot on a roll of original negative
CAMERA ORIGINAL	The original film element exposed in the camera, often the original negative
CANCELLATION	The cancellation of sound distortion on a photographic sound track by neg pos printing
CANDELA	A unit of luminous intensity of light
CAPSTAN	A smooth or toothed drive spindle for film or tape
CAPTION	Written or spoken titles to a picture or illustration
CARTRIDGE	Container with a spool of film, or a closed loop of film
CASSETTE (1)	A light tight container for a roll of film for attachment to a daylight operating film processor
CASSETTE (2)	A sound tape cartridge, or a video tape cartridge
CC FILTER	Optically flat colour correction filters made of gelatine in RGBCMY and intervals of 0.05 density (Kodak term)
CCD	Charge coupled device (*see*)
CCIR	Consultative Committee for International Radio, standardizing body for television and radio
CEL	Transparent foreground used for animation filming
CELL SCRATCH	Scratch on the base or cell (celluloid) side of film = base scratch
CELL SIDE	The base (or celluloid) side of a piece of film
CELLULOID	Trade name for cellulose nitrate, occasionally used for all film
CHARACTERISTIC CURVE	A graph of Log *E* and Density for a film stock
CHARGE COUPLED DEVICE	Semiconductor which can store information, used as an image sensor
CHECKER-BOARD CUTTING	A and B roll cutting (syn)
CHEMICAL TONING	*see* Toning bath/toner
CHROMA	Television signal component carrying colour, also loosely = saturation
CHROMAGENIC	Production of colour by a chemical process, used of colour development, and certain toning processes

CHROMAKEY	Video special effect combining images with a blue background with other images, similar to travelling matte
CHROMINANCE	Refers to a video signal that determines the colour of the image
CINCH MARKS	Scratches caused by excessive tension during the winding up of film, especially by cinching
CINCHING	Pulling the end of film to tighten the wind of loosely wound film, very bad practice
CINE	Colloquial term for any motion picture practice or equipment
CINEMASCOPE	Trade name for an anamorphic widescreen film system
CINEMATOGRAPHY	General term for intermittent motion picture film technology
CINEX STRIP	A short test print in which a frame from each scene has been exposed with a test exposure
CLAPPER	Hinged arms clapped together and filmed by camera to establish film/sound synchronization
CLAW	Device to pull film through the camera or printer gate intermittently
CLEARING BATH	Aqueous solution used to ensure staining reduced to a minimum, chemistry depends on the process
CLIP	Short section removed or replaced from a film sequence or scene
CMY	Cyan, Magenta, Yellow, the subtractive primaries, also print grading lights (in Technicolor)
COCKLE	Unevenly shrunken film resulting in uneven wind (*see also* Buckle)
COLLIMATED	Of light in a parallel beam, produced by condensing lenses
COLORIMETRY	The measurement of colour in numerical terms
COLORIZATION	Electronic addition of colour to a black and white film for colour TV transmission
COLOUR	A general term for the subjective sensation of viewing different wavelengths of visible light. (USA Color)
COLOUR ANALYSER	*see* Analyser; colour grading electronic video device
COLOUR BALANCE	Term used to describe the 'neutrality' of a colour film or TV image or its departure from neutral; *see also* Balance
COLOUR CONTRAST	The subjective effect of the intensities of two colours, numerically the log of this ratio
COLOUR CORRECTION	Adjustment (by grading) of an off balance print or image to a correct balance
COLOUR DEVELOPER	Aqueous solution of a colour developing agent to produce dyes in film emulsions chromagenically
COLOUR FILTER	A transparent gelatine or glass for selectively absorbing light wavelengths
COLOUR NEGATIVE	A record of colour and brightness of a scene in terms of negative values of brightness and complimentary colours
COLOUR POSITIVE	A record of the original scene in identical brightness and colour values
COLOUR PRINT	A photographic colour positive made from a different camera original by printing
COLOUR SEPARATIONS	Black and white film negatives or positives made through tricolour filters that represent R, G or B records of a scene
COLOUR SYSTEM	Trade name or traditional name of a colour film process or technique
COLOUR TEMPERATURE	A method of describing the colour of a light source, by comparing with the temperature in Kelvin units of a black body irradiator
COMBINED PRINT	A film print with both picture and sound track, a married print (*see*)
COMMENTARY TRACK	A sound track with a voice or commentary over the background sound

COMOPT	Combined Optical sound track, a photographic sound track on a print
COMPLEMENTARY COLOURS	Colour resulting from removing a colour from white light, e.g. the complementary of yellow is blue, OR two colours when added together produce neutral white or grey
COMPOSITE PRINT	Combined print (syn)
CONDENSER LENS	A lens, or lens system, able to collimate light, i.e. generate a parallel beam
CONDENSING	Creating a peeled roll (cf.) (Technicolor)
CONFORMING	The assembly of picture and sound elements to match an edited film or video production
CONSERVATION	The processes necessary to ensure the physical survival of the film with minimum degradation
CONSERVATION MASTER	Term for a duplicate made primarily for long term archival storage
CONTACT PRINTING	Printing a film by exposing the raw stock in contact with the original
CONTINUOUS PRINTING	Printing film by continuous, not intermittent, transport of the original and the print
CONTINUOUS PROJECTION	Projection by continuous film transport, the intermittent image is created by a mirror or prism system.
CONTRAST	Relationship between light (highlight) and dark (shadow) areas of a picture, described as high, low or a number (numerically the log of this ratio)
CONTROL TRACK	A magnetic sound track on a film controlling the distribution of other tracks to loudspeakers
COPY	A film print, a colloquial general term
CORE	A cylinder used as a centre for winding film, usually plastic, originally wood
COUNTER	Device for measuring the length of a film by counting frames
COUPLER/DYE COUPLER	A chemical that combines with oxidised developing agent to form a dye, chromagenic
CP FILTER	Colour printing filters, for use in uncollimated light, in primary colours and increments of 0.025 or 0.05D
CRAWLING TITLES	Titles or credits travelling horizontally across the screen
CREDITS	Acknowledgements in the titles at beginning or end of a film
CREEPING SYNC	A progressive error in synchronization between picture and sound
CRI	Colour Reversal Intermediate, a defunct Kodak duplicating system
CROPPING	Cutting off the top or sides of a frame to change the aspect ratio
CROSS MOD TEST	A cross-modulation test determines the optimum printing exposure to achieve cancellation (cf.)
CROSSOVER (TEST)	Sensitometric test when converting printing conditions from one batch of film to another
CU	Close up
CUE	A signal or mark to actuate an event, on a film
CUE DOTS	Visible signals to indicate the reel change over between film projectors or telecine
CUE SHEET	List of printing details for a roll of film
CUT	A change from scene to scene
CUTS AND TRIMS	Unused negative film from scenes, takes and parts of scenes, left over from editing
CUTTING	Selection and assembly of scenes of a film
CUTTING COPY	Laboratory term for the editors cut film, ready for negative matching

CUTTING FRAMES	Extra frames at start and end of scenes to allow latitude in editing, particularly in animation
CYAN	Subtractive primary
D LOG *E* CURVE	Characteristic curve (syn)
DAILIES	Rushes, American term
DAT	Digital audio tape
DAYLIGHT	A colour balance of 5400°K, for 'daylight' colour film
DENSITOMETER	A device for measuring the density of film
DENSITY	A measure of the 'blackness' of film. D = Log 1/Transmission
DEPTH OF FIELD	Range of object distances from a camera, at a specific aperture, over which the image is acceptably sharp
DEPTH OF FOCUS	Range of image distances from a camera film plane, at a specific aperture, over which the image is acceptably sharp
DESENSITIZATION	Treatment of film to reduce the photographic speed or contrast, usually by a solution
DEVELOP	The process of chemically magnifying a latent image on a film
DEVELOPER	The aqueous solution of developing agent used to develop a latent image
DIAPHRAGM	Iris device for controlling light transmission by a lens
DIAPOSITIVE	Direct positive, a reversal film. Term mostly used by French and German manufacturers
DICHROIC	The property of certain crystals or solutions to transmit and reflect different wavelength bands. In practice a glass filter selectively reflecting, and transmitting wavelengths of light, especially used in beam splitters
DIFFUSE	Scattered, non-specular, light
DIFFUSER	Translucent glass or filter to diffuse a specular beam of light
DIN	Deutsches Institut für Normung, the German standards organization, also a speed standard
DISSOLVE	A visual transmission from one picture to another
DOLBY	Trade name for a noise reduction system for photographic and magnetic sound
DOPE SHEET	Sheet of instructions for shooting scenes, story board (syn)
DOUBLE-COATED FILM	Film coated with emulsion on both sides of the film base
DOUBLE EXPOSURE	Two separate exposures on the same film
DOUBLE-HEADED	Two reel projection method, image on one reel, sound on separate magnetic sprocketed film
DOUBLE REEL	A roll of film, a unit of film as part of a film programme, usually about 2000 ft
DOUBLE-SIDED SOUND TRACK	A photographic sound film with two tracks, one in one direction, one in the other (*see* Up-and-down tracks)
DOWSER	Device for blocking the projector light to prevent nitrate film igniting
DROPOUT	Short loss of signal in a magnetic recording, due to loss of head contact or faulty tape
DRUM	A large diameter cylinder optical sound film passes round to ensure uniform movement on a reproducer
DRY RUN	A trial camera take without film
DUALATERAL SOUND TRACK	A photographic sound track with two identically oriented unilateral variable area tracks side by side
DUBBING (1)	Transfer of a video signal from one format to another
DUBBING (2)	Combining several sound components into a single record
DUPES	A loose colloquial term for any duplicate film element

DUPLEX SOUND TRACK	A photographic sound track with two identical unilateral mirror image variable area tracks side by side
DUPLICATE	A copy or reproduction of a film element, often used loosely to mean a duplicate negative
DUPLICATION	The procedure of making a duplicate film element
DUPLITIZED (film or positive)	US term for double-coated film (*see*)
DYE	Chemical substance capable of colouring a material
EDGE NUMBER	Groups of numbers (and letters) sequentially placed along a film edge (usually 1 ft apart)
EDIT	The process of decision and action in assembling the sequence of a film or video programme
EDIT SYNC	Level sync (syn)
EDL	Edit decision list; the list of time code and source of video (or film) edits
EFFECTS TRACK	A sound track, film or tape containing special sound effects only
EI	Exposure Index, roughly equivalent to ASA speed rating, used at a time when the ASA value for cine film had not been standardized
ELEMENT	The film component in a film production procedure, e.g. original negative, dupe negative, print, etc.
ELEVATOR	Mechanical device to allow film to be loaded or unloaded from a processor without stopping the transport
EMULSION	The light-sensitive layer of a suspension of silver salts in gelatine coated onto film base
END OUT	Tail out (syn), i.e. a reel which has the end on the outside
END-TO-PAPER SECTION	Method of indicating to a printer operator the section of film to be printed, a paper marker is placed in the roll
ENG	Electronic news gathering
ERASE	Procedure of removing a previous recording from a tape or magnetic stripe
ESTAR	Kodak trade name for their polyester film base
EUREKA EU95	Proposed European 1250 line PAL compatible HDTV broadcasting system
EVEN SYNC	Level sync (syn)
EXCHANGE, FILM	A regional centre used for distribution, repair and checking of cinema release prints
EXCITER LAMP	Lamp used as light source in a photographic sound reproducer
EXPOSURE (1)	The process of subjecting film to a light image
EXPOSURE (2)	The total light energy falling on film, Intensity × Time, usually expressed as Log to base 10
EXPOSURE METER	Device for estimating the correct aperture to achieve optimum exposure, also called a light meter
f NUMBER	Relative aperture of a lens opening, focal length divided by diaphragm diameter
FADE (OF DYES)	Gradual loss of saturation and sometimes colour changes with time
FADE (SPECIAL EFFECT)	A gradual reduction of exposure of film or video to black, also called fade-in
FADE-IN	A gradual reduction of exposure of film or video to black
FADE-OUT	A gradual increase of exposure of film or video from black to an image
FADER	Shutter mechanism for producing fade-ins or fade-outs during printing
FALL OFF	Unevenness in brightness, usually of a projection screen

FIAF	Federation Internationale des Archives du Film
FILM	A light sensitive emulsion coated on a flexible base
FILM BASE	A flexible support on which a photographic emulsion is coated
FILM SPEED	Sensitivity of film to light, determined numerically by various national standard methods, ASA, DIN, BS
FILMSTRIP	A length of film with still frame images, usually in still formats
FILTER	Transparent material that selectively absorbs wavelengths and alters the colour of light
FILTER PACK	A collection of filters used together; usually in printing
FINE CUT	A final edit to improve the editing of a 'rough cut'
FINE GRAIN (1)	A colloquial term for any black and white intermediate, negative or positive, made on a special duplicating film
FINE GRAIN (2)	Kodak term for a special black and white duplicating film
FIRETRAP	A device to prevent burning nitrate film in a projector (or a vault) from igniting other film
FLARE	Scatter of light in an optical system that produces non image forming exposure and reduces contrast
FLASH FRAME	A single overexposed negative frame of film, accidental or intentional as a marker when printed
FLASHING	The technique of giving print or duplicating film a low overall exposure to reduce contrast
FLAT	Low in contrast
FLICKER	Random or regular variations in screen brightness
FLOAT	A periodic vertical movement of a projected image, result of a mechanical defect
FLOOD TRACK	A photographic sound track exposed across the entire area as a test of sound camera or processor
FLOP-OVER	Optical special effect in which the printed image is reversal from right to left
FLUTING	Film distortion or cockle where edges are stretched more than centre, also called edgewave
FLUTTER	A rapid periodic frequency variation in an optical or tape sound track
FOCAL LENGTH	Distance from lens centre to the point at which an image of a point at infinity is focused
FOCAL PLANE	The plane at 90 degrees to the lens axis at the position at which the image is formed
FOCUS	Position or state of the most well-defined image produced by a lens
FOG LEVEL	The lowest density of a film material where no exposure has occurred
FOG, TO	To expose film to non-image forming light, usually accidental
FOOT	British distance measure, widely used in film industry; 1 m = 3.2818 ft
FOOTAGE NUMBERS	Edge numbers (syn), because they generally occur every foot of film
FORCED DEVELOPMENT	Development for longer than the usual time to gain speed, usually at the expense of graininess
FORMAT (1)	The film gauge, image dimension, perforation arrangement
FORMAT (2)	Size and/or aspect ratio of a film, sometimes used to mean the entire presentation
FPM	Feet per minute, used to describe film transport speeds in the UK and USA, e.g. film processors
FPS	Frames per second
FRAME	An individual picture image on a film

FRAME COUNTER	Device for counting frames as the film is wound through
FRAME LINE	The space between one frame and the next
FRAME RATE	The number of frames exposed, or projected, per second
FRAMING	Adjusting the frame position in a projector or printer gate to include all the frame or crop as required
FREEZE FRAME	Optical printing effect when one frame is repeatedly printed so that the image appears stationary
FRINGE/FRINGING	A defect due to poor registration of component images
FRONT END	General term for all work up to the answer print stage of a film production
FRONT PROJECTION	Image projection onto the front of a screen, also a film background effect using the technique
GAMMA (film)	The slope of the straight line portion of a characteristic curve of a film, an indication of contrast
GAMMA (television)	The relationship between log luminance on a monitor to the original scene
GATE	The aperture through which a film is exposed or projected; in cameras, printers and projectors
GAUGE	Width of film usually in millimetres
GEL	Loose colloquial term for a flexible filter
GELATINE	Flexible protein matrix used to carry the light sensitive salts and coated onto the film base
GENERATION LOSS	Degradation of picture quality resulting from successive printing, transfers or dubbing of film or video
GRADER	The technician responsible for the quality and balance of a film print (US Timer)
GRADING	The technique of controlling and adjusting the overall density and colour balance of a film print (US Timing)
GRAIN	The physical structure of a film image, seen as clumps of silver or dye
GRAININESS	The subjective visual effect of grain in film
GRATICULE	A cross pattern on a glass plate to assist alignment in some optical equipment, e.g. printers
GREEN	Additive primary colour
GREEN FILM	Film immediately after processing and still difficult to project smoothly
GREY SCALE	A scale of neutral grey images on film or paper, test material for measuring photographic responses
GUIDE TRACK	A speech track made as a guide to actors re-recording the speech later in a studio
H & D CURVE	Characteristic curve (syn) old term (from Hurter and Driffield); only used in UK
HALATION	Images caused by the scatter or internal reflection of light within a film
HALF FRAME	A frame on 35 mm film 21 × 8 mm, instead of 21 × 16 mm
HALF-TONE	Tonal differentiation by evenly spaced dots of different sizes, graphic arts technique
HALIDE	A metal salt of a halogen, fluorine, chlorine, bromine or iodine
HARDENING BATH/HARDENER	A solution of chemicals for hardening film emulsion, e.g. alums
HASH MARKS	Cue marks scratched onto release prints, 'unofficial'
HDTV	High definition television
HEAD OUT	A film or tape roll with the head on the outside, i.e. opposite of

	tail out (*see*)
HEAD, OF EQUIPMENT	Any device that senses or transduces a signal, tape, sound etc.; a transducer
HEAD, OF FILM	The start end of a film
HEAT FILTER	A filter, usually glass for absorbing heat, infrared light
HI ARC	Old carbon arc lamp operating at a high current density
HIGH BAND	A video tape producing broadcast quality pictures
HIGH KEY	A scene in which almost all the tones are high in brightness, opposite of low key
HIGH SPEED PHOTOGRAPHY	Operating a camera faster than normal, to slow down motion, more than 150 frames per second approx.
HIGHLIGHT	The brightest part of a scene or its reproduced image
HOLD FRAME	Freeze frame (syn)
HOLD TAKE	Negative of a scene to be held for later possible use, not selected for rush printing
HORSE	A horizontal spindle holding one or several rolls of film
HOT SPOT	The brightest part of an unevenly illuminated projection screen, or video monitor screen
HUB	A core (syn) (American?)
HUE	The visible character of a colour as defined by its position on the visible spectrum or CIE colour diagram
HYPERSENSITIVITY	Increasing the speed of camera film by preflashing or chemical methods
HYPO	An old term for sodium thiosulphate, the most common fixing salt
HYPO ELIMINATOR	A solution for removing unwashed out fixing agent from film emulsions, to increase the life of the silver image
IMAX	Wide-screen motion picture system, 70 mm film, horizontal run, 15 per frame, 70 × 46 mm.
IMBIBITION	A mechanical printing method where an image is formed from dye transferred from on film to another, e.g. Dye Transfer, Technicolor etc.
IN RACK	Term for 35 mm film meaning that every frame of a reel is exactly 4 perforations from the next
INCOMING SCENE	The second scene in a dissolve
INFRARED	Wavelengths of light just longer than the visible spectrum, subjectively discerned as heat
INTEGRAL TRIPACK	A tripack (syn)
INTER-DUPE	A duplicate colour negative derived from an interpositive, local term, probably Technicolor
INTERCUTTING	Editing the same or similar scene into several different positions in a story or sequence
INTERLABORATORY SURVEY	A regular Kodak survey of world motion picture laboratory processing quality and consistency
INTERMEDIATE	General term for colour film master positives and negatives on a integrally masked film.
INTERMITTENT	Film movement when each frame is held stationary and moved on frame by frame
INTERNEGATIVE	A duplicate colour negative film, especially one prepared from a reversal camera original or a print
INTERPOSITIVE	A term for any positive element used as an intermediate stage, i.e. not the final print
INTERTITLES	Titles or caption frames cut between scenes in silent movies
IPS	Inches per second

IRIS	A device used to vary the opening of a lens diaphragm
IRIS WIPE	A wipe effect in the form of a increasing or diminishing circle, i.e. iris in, or iris out
JOG	A facility to move a film or video one frame at a time, or by small increments
JOIN	A splice or edit between two pieces of film or tape
JUMBO ROLL	The widest roll of coated film or tape before slitting and perforating
JUMP CUT	A sharp edit, or a removal or omission of a section of scene, resulting in a jump in the action
K	Kelvin
KELVIN	The unit of colour temperature of a light source
KEY NUMBERS	Edge numbers, footage numbers (syn)
KEYSTONE DISTORTION	Image distortion on projection when the projector axis is not at 90 degrees to the screen
KINESCOPE	A television image recorded on film (USA, *see* Telerecording)
KODATRACE	Kodak trade name for a translucent diffusion material
LACE	To thread up a projector, printer, tape recorder or any equipment with film or tape
LACQUER	A coating material to protect film or hide scratches, a varnish or other material
LAD	Laboratory Aim Density, a density value used to control the production of intermediate film materials
LAKE	An insoluble metal/organic pigment formed by precipitation from solution
LAMBERT	L, a unit of surface brightness
LAP DISSOLVE	Overlapping dissolve, where two film images overlap as one fades in and the other fades out
LATENSIFICATION (1)	Flashing (syn) (USA)
LATENSIFICATION (2)	The intensification of an under-exposed latent image by controlled fogging before development
LATENT IMAGE	The undeveloped invisible image on photographic film prior to development
LAVENDER	The 1930s Kodak film stock for making duplicate black and white negatives; had a pale blue base
LEADER	The length of film prior to the story, giving identification, protection and other information
LENS	Optical device for generating an image in a camera, printer or projector
LENS APERTURE	The opening of a lens, expressed as f number, or T stop (*see both*)
LENTICULAR	A corrugated or patterned surface of some early colour films
LEVEL SYNC	The situation when the picture and sound film records are in alignment and not offset as for projection or printing
LIGHT BOX	An illuminated panel for viewing film or control strips
LIGHT VALVE	A variable shutter mechanism for a printer
LINE FILM	Old term for orthochromatic film processed to a high contrast for titles or intertitles
LINEAR	Straight line, i.e. directly proportional, relationship, between input and output
LINING UP	Setting up any apparatus before use, especially a camera
LIP SYNC	Exact correspondence between picture and sound recording, also refers to simultaneous recording technique

LIQUID GATE	Where negative film, or both films, are immersed or coated with a liquid in a printer gate to minimize scratches
LITH FILM	Very high contrast sheet film used for titles, given a special development to achieve high densities
LIVE ACTION	Shots or real action rather than animation
LONG FOCUS LENS	Lens with a focal length longer than normal for the format
LONG SHOT	LS, scene showing a general view, from a distance
LOOP	Film joined to make a circle or continuous band, for testing purposes, or printing multiple copies
LOUDSPEAKER	Transducer converting electrical signals to sound
LOW BAND	A video tape recording system not reaching TV broadcast standards
LOW KEY	Scenes in which most subject tones are dark
LOW-PASS FILTER	Device to attenuate, minimize, high frequency sound
LUMEN	Measure of light as luminous flux
LUMINANCE	Brightness of a surface, often refers to a video signal determining brightness of the image
LUX	Unit of illumination, equal to one lumen per m^2
M AND D	Masters and dupes, i.e. all the elements of a feature film
M AND E	Music and effects, i.e. a sound track without the speech or commentary
M AND T	Often marked on cans, means both original negative (mute) and optical track negative are present
MAG/MAG TRACK	A magnetic track, often refers to a sprocketed magnetic film element
MAGAZINE	Light proof container for film
MAGENTA	Subtractive primary colour
MAGOPT	A motion picture film print with both optical and magnetic sound tracks on the one film
MAIN TITLE	The front (usually) section of a film with titles and credits
MAKE-UP	Assembly of the various elements of a film for printing (Technicolor?)
MALTESE CROSS	Mechanism for providing intermittent movement in a camera or projector
MARRIED PRINT	A film print with picture and sound correctly synchronized
MARRYING-UP	Assembly and preparation of film elements for printing to make a married print
MASK (1)	A film element whose image is used to modify the image on another film element when combined in register
MASK (2)	A frame to restrict the dimensions of an aperture in a camera (the outer mask) or printer or projector
MASK (INNER)	A mask (2) used to create vignettes or shaped images located behind the camera (or printer) lens
MASKING (COLOUR)	Using a mask (1) to modify colour saturation or hue of a film image
MASKING (CONTRAST)	Using a mask (1) to alter the contrast of a film
MASKING (INTEGRAL)	An image of unused coloured couplers, within the dye layers of a colour film to correct unwanted dye absorptions
MASKING (PRINTING)	A general term for using a mask (1) to combine with a negative to make a print
MASKING (PROJECTION)	A black border to a screen that limits the area of the projected image
MASTER (1)	A term used for a camera reversal colour film used for printing and never itself projected
MASTER (2)	A general term for a film element used as the start of a special sequence of printing
MATCH DISSOLVE	A dissolve where the object is constant but the background changes

MATRIX	Film with images (often in relief) in gelatine used in the dye transfer imbibition print processes, e.g. Technicolor
MATT	A surface with a diffuse (non-specular) reflection
MATTE	An opaque mask produced in order to restrict the image area for a special effect
MATTE BOX	A lens shade to hold filters or obscure a part of the image area
MICROFILM	Photographic record on 35 or 16 mm film of text for storage purposes
MICRON	0.001 mm or 10–6 m
MIRED	MIcro REciprocal Degree, 1 M/K (colour temperature). A unit of colour temperature filter control
MIX/MIXING	Loose term for combine, applied to sound, picture or a combination of both, or a dissolve (syn)
MLS	Medium long shot
mm	Millimetre
MODULATION	Amplitude variation, for example on an optical sound track
MODULATION TRANSFER FUNCTION	Also called MTF, measure of performance of a lens or contact print system to reproduce audio effects
MOIRE	Visual interference patterns formed by combinations of rasters, mosaics, or half tones
MONOCHROMATIC LIGHT	Light of only one wavelength (or nearly only one), e.g. sodium vapour
MONOCHROME	One colour reproduction, e.g. black and white
MORDANT DYE TONING	Old method of replacing silver images with basic dyes mordanted with silver salts
MOSAIC	A pattern of red, green and blue filters on film to create an additive colour system
MOTOR CUE	Cue dot (syn)
MOVIOLA	A film editing machine. Trade name, widely used for all editors
MULTI-ROLL PRINTING	'A and B' roll printing with many rolls, A, B, C, D, etc.
MULTI-TRACK	Magnetic recorder/recording having four or more parallel tracks on 35 mm/4, 8, 16, 24 tracks
MULTIPLEXER	Device to enable images from several sources to be transferred to film or video
MUSIC TRACK	Audio track of music only
MUTE	Describes a length of negative film without its associated sound track
MUTE AND TRACK	*see* M and T
MYLAR	3M trade name for their polyester film base
ND/ND FILTER	Neutral density filter
NEG–POS	Implying a negative–positive film system
NEGATIVE	Film image in reverse tones, high densities correspond to high brightness
NEUTRAL DENSITY	Grey neutral colour transparent filters or glass used to reduce exposure
NEWSREEL	A regular cinema magazine news programme
NEWTON'S RINGS	Optical interference patterns caused by two surfaces close together
NG	No Good, a laboratory term meaning faulty, must be redone
NITRATE	Cellulose nitrate/loose term for cellulose nitrate film stocks pre 1950
NOISE	Unwanted sound or signals in a video system, the last often producing grain-like image structure
NOTCH	Shallow cut along the edge of negative film to trigger the change of printing light
NUMBER BOARD	Slate (syn)

OFF-LINE EDIT	Edit of video material using low cost equipment prior to final broadcast quality edit, also used for film
OFF-SCALE	Outside the range of printing lights of a normal printer
OHP	Overhead projector
ON-LINE (EDIT)	Live, of editing directly linked to original material
OPEN REEL	A tape transport system with separate feed and take up, not enclosed in a cassette, reel to reel
OPTICAL AXIS	Axis from centre of the lens at right angle to the lens plane
OPTICAL PRINTING	Printing using an optical system, i.e. a camera and a projector
OPTICAL SOUND	Photographic sound track produced and read by modulation of a light beam
OPTICALS	General term for minor and major special effects made on an optical printer
ORIENTATION (FILM)	Film position in a projector; Type A = emulsion to light, Type B = emulsion to lens
ORIGINAL	The film element exposed in the camera, the first generation of image
ORTHO/ ORTHOCHROMATIC	Film sensitive to blue and green light only
OUT OF CONTROL	A term for a film process or control strip whose density readings are outside control limits
OUT-GOING SCENE	The first scene of a dissolve
OUT-OF-SYNC	Sound and picture not synchronized
OUT-TAKE	A take of a scene not selected for rush printing, or for the final edit
OVERCRANKING	Filming at a slightly higher speed than normal to slow action down, archaic term still in use
OVERLAP	Extending the sound track into the next scene (to improve continuity)
OVERLAY (1)	Superimposing one image on another, sometimes without a background
OVERLAY (2)	The foreground image or cel of an animation
OVERMODULATE	When the optical sound input signal is too great an amplitude for the system to handle
PAN	To rotate a camera horizontally
PAN/PANCHROMATIC	Of a film stock, sensitive to all wavelengths in the visible spectrum
PANEL (PRINTER)	A film printer with the film path on a flat panel layout, often bidirectional
PANORAMA	A wide image, also a trade name of several wide screen systems of the 1950s and 1960s
PAPER-TO-END SECTION	Method of indicating to a printer operator the section of film to be printed, a paper marker is placed in the roll
PAPER-TO-PAPER SECTION	Method of indicating to a printer operator the section of film to be printed, two paper markers are placed in the roll
PARAMETER	A number value used to specify a character or procedure
PARTICLE TRANSFER ROLLER	Device/roller with a special coating that removes dust particles from film
PATCH	A transparent piece of film used to repair a tear or break
PE	Polyethylene terephthalate, a polyester plastic used for a film base/ polyester
PEEL ROLL/PEELED ROLL	A roll created by winding a number of separate lengths of film onto a single roll without joining together
PEG ANIMATION	Animation shot by locating the sequences of artwork on registration pins

PEG BAR	The registration pins used for peg animation
PERFORATED SCREEN	A cinema projection screen perforated with small holes to allow the loudspeakers to be behind the screen
PERFORATIONS	The holes in film to permit transport, *see also* Sprocket holes
PERSISTENCE OF VISION	A visual effect that permits intermittent images to be seen as continuous
PHOSPHOR	A substance emitting light when irradiated by an electron beam, used for TV additive display
PHOTOGRAPHIC SOUND	Optical sound
PHOTOMETER	Instrument for measuring luminous intensity, at printer gates, screens, or for exposure determination
PHOTOMETRIC FILTER	Filter for converting one colour temperature light to another, correspond to mired values
PHOTOSENSITIVE	Anything sensitive to light by incurring some sort of change
PILOT PIN	*see* Pin
PILOT TONE	A camera speed control system using a tone recorded on the sound tape
PIN/REGISTER PIN	Camera or printer device which engages a film perforation in order to arrest and retain a film position during exposure
PINHOLE	A small clear faulty mark on a negative. Result of error in processing, camera, or manufacturing
PITCH (FILM)	The distance between successive points on a film, e.g. sprocket to sprocket
PIXEL	The smallest element on a raster display, a picture cell with specified colour and/or intensity
PIXILLATION	Motion effect produced as a result of photographing still pictures
PLATE	A still photograph used as a background in special effects
PLATEN	A surface used to support animation cels and materials
PLAYBACK	Play or reproduction of a recording
POINT	A unit of printing light control, one point is $0.025 \log E$, and nominally a 50 point scale
POLYESTER	Polyethylene terephthalate, a polyester plastic used for a film base/polyester
POSITIVE	A reproduction of a scene, highest brightness seen as clear film
POST-PRODUCTION	Film and video programme production from editing to release
POST SYNC	Synchronizing picture and sound track after the photography has been done
POSTERIZATION	A picture produced with a limited no of flat colours or specific tones, image gradation eliminated
PRE-FLASHING	Flashing (*see*) of print stocks to reduce contrast
PRE-RECORDED	Sound material for a programme that is already recorded
PRE-ROLL	Time required by a projector or telecine to provide a stable image
PREBATH	The first solution of a process, usually a solution for softening remjet backing on colour film
PREHARDENER/ HARDENER	A hardening solution used as a first process to prepare for a high temperature film process
PREMIERE	The first public showing of a feature film
PRESERVATION	The practices necessary to ensure permanent accessibility to the image content of the film
PRESSURE PLATE	That part of a printer camera or projector that holds the film flat in the gate
PREVIEW	A first look, also a special presentation of a feature film prior to premiere or release

PRIMARY COLOURS	Three colours capable of mixing (additive) or combining (subtractive) to reproduce all others
PRIME LENS	The lens most used for a format, conventionally a focal length equal to the diagonal of the frame
PRINT	A projection positive made by printing from another film element
PRINT-THROUGH (1)	A test procedure printing a control strip onto its print stock and measuring the sensitometric response
PRINT-THROUGH (2)	Unwanted transfer of signal on a magnetic tape from adjacent windings
PRINTED-IN	Term for any image defect (e.g. scratch or sparkle) copied from a previous generation, i.e. uncorrectable
PRINTER	A device for exposing an image on one film onto another
PRINTER LIGHTS	*see* Point (syn) or printer point
PRINTER POINT	*see* Point (syn)
PRINTER TAPE	Punched tape (syn); paper tape with punched holes to indicate printing lights and cues
PROCESS/PROCESSING	The wet chemical procedure of development of the latent image and subsequent stabilizing stages
PROCESS FILM	High contrast film used for producing high contrast images
PROCESS SHOT	Loose term for a special effect of separate background and foreground shots combined
PROCESSOR	Equipment for processing, washing and drying film
PRODUCTION DUPE	Duplicate negative made for multiple release printing
PROJECTOR	Apparatus for presenting motion picture images on a screen
PROTECTION MASTER	A film element made for preservation in case of damage to the original or other duplicate
PROTECTIVE MASTER	Protection master (syn – Technicolor?)
PTR	Particle transfer roller (*see*)
PULL-BACK	A technique in printing film in which the master is pulled back some distance in order to repeat print a section of film
PULL-DOWN	The operation of moving film from one frame to another, camera, printer or projector
PUNCHED TAPE	Paper tape with punched holes to indicate printing lights and cues
QUADRAPHONIC	A four-channel sound system
RACK	Term for the alignment from frame to frame of 35 mm film; *see also* In rack
RACKING	Framing (syn)
RAIN	A multitude of short vertical scratches on film, usually caused by cinching
RASTER	The scanned line structure of a TV screen
RAW STOCK	Colloquial term for unexposed film
RB	Same as NG, No Good (*see*). Used mostly by Technicolor
REAL TIME	Keeping pace with the events in the 'real' world. At normal speed
REAR PROJECTION	Projection onto the rear of a screen, viewed from the front
RECIPROCITY LAW	The 'law' that states that a constant exposure results in a constant result regardless of the intensity of the light
RECIPROCITY LAW FAILURE	Divergence from the reciprocity law by some photographic films at very high or low intensities
RECONSTRUCTION	The editorial procedure of reassembling a version of a film production to an authoritative original version
RED	An additive primary colour
RED MASTER	A local term for a conservation master where the silver image is replaced by silver sulphide

REDUCTION	Mixing multitrack master sound tapes to make a single tape for production
REDUCTION PRINTING	Reducing the image size by optical printing, e.g. 35 mm to 16 mm
REEL (1)	A roll of film, a unit of film as part of a film programme, usually about 1000 ft
REEL (2)	A flanged hub holding film
REEL-TO-REEL	Open reel (syn), separate supply and take up reels, of a film or tape path
REFRACTION	Deflection of a light path when passing from one medium to another, where the refractive indices are different
REGISTER PINS	*see* Pin
REGISTER/REGISTRATION	To cause two or more images to coincide exactly
REGISTRATION	Process of registration. To place in exact alignment
REHALOGENATION	A process of reforming the silver halides after developing to silver, used in some colour processes for colour or sound
RELEASE PRINT	Feature film print made for cinema display
RÉSEAU	The mosaic of R, G and B filters printed on Dufay colour film
RESOLUTION	The ability of a reproduction system to discriminate between images of objects very close together
RESOLVING POWER	Resolution of a reproduction system expressed numerically, sometimes in lines per mm
RESTORATION	The process of compensating for degradation by returning an image or artefact to close to its original content
RETAKE	To photograph a scene again, usually due to an error the first time
RETARD ACTION	Special effect of slowing action by repeat printing of frames (USA)
RETICULATION	Distortion, cracks and wrinkles on film emulsion caused by sharp temperature changes during processing
REVERSAL EXPOSURE	The exposure of film during processing in order to 'reverse' the image, and produce a positive
REVERSAL FILM	Film designed for reversal processing
REVERSAL PROCESS	A film process that produces a positive image directly, using two developer stages
REVERSE ACTION	An optical effect when the action appears backwards/frames printed in reverse order
REVERSE DIRECTION	Picture image reversed, left to right, = Flopover (syn)
RF CUES/RF TABS	Metal foil reflective to radio frequency used as film printer cues, attached to film edges
RGB	Red, green and blue, the order of printer points used to describe a printer setting for a scene
ROCK AND ROLL	Moving a sound track and picture backwards and forwards in sync to locate edit points, also term used for video
ROLL (1)	A general term for a rolled length of film
ROLL (2)	A loose term for a reel or length of film, usually a term used for film on a core
ROLLING TITLE	Title or captions moving from bottom to top on the screen
ROPING	Film damage indentations caused by film running off a sprocket drive, also called run-off
ROSTRUM CAMERA	A camera mounted vertically over a platen or graphics, for complex titles or animation
ROTARY PRINTER	A continuous motion contact printer, the gate is curved to ensure good originals and stock contact
ROUGH CUT	A first edit that may be improved later by 'fine cutting'

RUBBER NUMBERS	Edge or footage numbers applied after processing by a letterpress printing process
RUN OFF	The accident of film running off a sprocket drive causing subsequent 'roping'
RUN OUT	Any piece of film after the tail leader as a protection for the reel
RUN UP	Film on the front of a reel to allow the projector to reach a stable speed
RUSHES	First print from a negative, often made quickly, or overnight to see the following morning, British term
RUSHES REPORT	Written report from a grader describing the negative and rushes quality for the cameraman
SAFE AREA	The area of a format shown on a 1.33:1 AR TV screen
SAFELIGHT	A light source with a filter to protect a film from fogging but allow the operator to see
SAFETY BASE	Any non-cellulose nitrate film base that is not so inflammable
SAMPLE PRINT	A print made as a sample of a bulk production of release prints
SANDWICHING	Two image films in register with a print raw stock in a contact printer
SATURATION	The spectral purity of a colour, the degree of other wavelengths present
SCAVENGER	A processing solution for removing damaging chemicals from a film emulsion
SCENE	A single subject filmed by a single film shot
SCRATCH	Abrasion of film, either of the base material or the gelatine emulsion
SCREEN	Stretched material as the image display vehicle for a film projector
SCRIPT	Written scene by scene statement of a film story
SCROLLING	Adding a new line at the bottom of rolling titles
SECOND NEGATIVE	A negative take that is not rush printed
SECTION PRINT	A print of a part of a roll of film
SENSITOMETER	Device for exposing a film control strip to precise exposures
SENSITOMETRY	Study of the effect of light on film, the relationship between exposure and density
SEPARATION	Process of using a tricolor filter to make a separation record
SEPARATIONS	A photographic record of red, green or blue components of a scene
SEPMAG	Magnetic sound record, separate from the picture film, displayed by double headed projection
SEPOPT	Separate Optical, a term for separate optical sound track and negative or print. an archaic term
SEQUENTIAL FRAME	Three colour separations on one film, in sequence red, green, blue
SET	An artificial scene constructed in a studio or stage
SHOOT	Colloquial term for operating a camera
SHORT END	A piece of film left at the end of a roll, often removed before processing to use for shot scenes
SHOT	A single operation of a camera
SHOW PRINT/SHOW COPY	A selected carefully produced print, a corrected answer print
SHRINKAGE	Reduction of dimensions of a film by loss of plasticizer or internal water
SHUTTER	Device for producing a short exposure on a film
SHUTTLE	Play a film or video forward and back (in an editor for example) to search
SIGNAL-TO-NOISE RATIO	The relationship between unwanted noise and required signal (in video). Noise appears like grain

SILVER	Metallic silver is the opaque material developed during processing monochrome film
SINGLE FRAME	Expose or project one frame at a time, i.e. slowly
SINGLE SHOT	Single frame (syn)
SINGLE SYSTEM	Recording film and sound on one single film, the old optical system or more recent magnetic system
SKIP FRAME	Optical effect in which frames are omitted regularly in order to speed up the action
SKIVINGS	Fine slivers of film created by the slitting process, in manufacture or after processing
SLASH DUPE	Black and white (usually) dupe neg made as a rough record without much care
SLATE	A board, usually black, marked with scene and shot details and filmed before a shot
SLIDE	A transparent still film image used for projection
SLIT/SLITTING	Cutting film during manufacture or after processing to produce the final film width
SLO-MO	Colloquial for slow motion
SLOPE	Steepness of a curve or graph, e.g. gamma, calculated as Tan angle, or gradient of a straight line
SLOW MOTION	Operating a camera faster than normal, to slow down motion, not as fast as high speed photography
SMPE	Society of Motion Picture Engineers, original name (USA)
SMPTE	Society of Motion Picture and Television Engineers (USA)
SNOW	Random noise interference on a TV screen, sometimes severe sparkle (*see*) on film
SOFT EDGE	A diffuse edge to detail or to a matte or wipe edge, intentional or not
SOFT FOCUS	Slightly out of focus, refers to a print or a projected image
SOLARIZATION	A positive image in which the highlight densities are reversal in response, result of overexposure, some toning effects or accident
SOUND GATE	The position at which a negative optical track is exposed onto the print stock on a printer
SOUND HEAD	On a reproducer or projector the transducer reading the optical or magnetic sound track
SOUND NEGATIVE	A positive optical film sound track image, i.e. a sound track on a print
SOUND POSITIVE	A negative optical film sound track image, i.e. a sound track on a negative film
SOUND TRACK	A general term for any optical or magnetic film or tape record of sound
SOUND-ON-FILM	General term for a combined image and sound on a film, usually a print
SPARKLE	Images of dust on the negative (usually) on a print film
SPECIAL EFFECTS	General term for an illusion or distortion of time or reality, in film or video
SPECTRUM	The full range of visible wavelengths of light
SPEECH TRACK	Any sound track with voice only, i.e. no music or effects, any element
SPEED (general)	General term for the frame per sec, or ft per sec rate of cameras, printers and projectors
SPEED (photographic)	Photographic speed is a numerical (usually a national standard) value for the sensitivity to light of a film

SPLICE	Any join in a length of cinematographic film
SPLIT SCREEN	Optical effect of two or more separate image within a single frame
SPOKING	Distortion in a roll of film so that the roll appears angular, not round, usually repaired by rewinding
SPOOL	Flanged film roll holder for projection
SPOOL, TO	To wind up onto a reel, core or spool
SPROCKET	A tooth or a toothed drum or wheel used to drive or transport a sprocketed film
SPROCKET HOLES	The perforations in film by sprockets to transport film
SQUEEGEE	Flexible wiper blade for wiping away liquid
SQUEEZED	Loose term for an image with anamorphic compression
ST	Sound track
STAR FILTER	Filters that produces star pattern effects on images of light sources
STARBURST	An effect of a rotating star increasing in size inserted as a short transition between scenes
STATIC	High electrostatic voltages, the result of friction, that fog or expose unprocessed film
STATIC MARKS/TREES	Images, often treelike or spidery, caused by static electricity
STEP PRINTING	Film printing frame by frame. Not continuously
STEREO	Colloquial for stereophonic or stereoscopic
STEREOPHONIC	Of sound reproduction involving at least two channels, giving the impression of reality and spatial distribution
STEREOSCOPIC	The appearance of a three-dimensional image, usually two images related by vision to specific eye
STILL FRAME	A series of single frames separated from a moving record
STOCK	A general term for any cinematographic film (often unexposed)
STOCK NUMBERS	Term for edge data, usually codes for the type of film, also the edge/footage numbers
STOCK SHOT	A library shot commonly used and reused
STOP FRAME	Freeze frame (syn)
STOP MOTION	The procedure of operating a camera manually one frame at a time
STORY BOARD	A series of still pictures or cartoons representing each scene of a film or video
STRETCH FRAME (PRINTING)	Optical effect in which frames are repeated regularly in order to slow the action down
STRIP (1)	Part of a wide roll of manufactured film slit into a single film length
STRIP (2)	Any short length of film particularly for process control purposes
STRIPE	A narrow magnetic sound recording band on cinematographic film
STRIPING	The process of applying a magnetic sound stripe to film
SUBSTRATE	Alternative term for subbing layer, also a term for any film base material
SUBTITLE	A title at the bottom of a motion picture frame usually to convert the sound track language or for the deaf
SUPERIMPOSE	Two or more images on a single frame, by multiple exposure on film
SURROUND-SOUND	A general term for 360 degree sound, quadraphonic or better
SWEETENING	A general term for improving sound quality and matching it precisely to a film image
SYNC	Synchronization
SYNC MARK	A mark, usually X, on one film frame to indicate synchronicity with a sound track ‘blip’
SYNC PULSE	A short sound on an optical or magnetic track to be synchronized with a sync mark on a film

SYNCHRONIZATION	The process of aligning any separate sound track with a picture image
SYNCHRONIZER	Device for running two or more film and/or sound track films at once and achieving synchronization
SYNCHRONIZING	The operation of correctly aligning the picture and sound records
SYNTHESIS	The process of reproducing a colour image from the analysis records (usually to R, G and B light)
T-STOP	Measure of actual light transmission through a lens at varying apertures
TABS	Colloquial term for RF cues
TAIL	The end of a film
TAIL OUT	Of a reel of film which is end out, i.e. the end is on the outside
TAKE	One of a series of filmings of one scene
TAKE-UP	Machine device that winds up film onto a roll
TAKE-UP, TO	To wind up film into a roll
TAPE (1)	Usually unsprocketed magnetic sound or video recording strip material
TAPE (2)	Clear tape for butt splices
TAPE SPLICE	Usually a butt splice made with a clear tape, several different tape widths available
TELECINE	Equipment for transferring film images to video tape
TELEPHOTO LENS	A camera lens with a long focal length and a short back focus
TELERECORDING	Old method of transferring a TV or video image to film by filming a monitor (with a fast pull-down camera)
TEST FILM	Specially made film with images for testing projector, printer or film characteristics
THAW	A return to action after a freeze frame effect
THREAD	Lace (syn)
THREE-COLOUR	A colour system using three analysis (and three synthesis) primary colours, additive or subtractive
THREE-D/3-D	Three-dimensional, of 3-D effects, film, TV
THREE-PERF/3-PERF	35 mm film shot in a 3-perf pull-down camera, a higher AR than normal
THREE-STRIP	Three separate colour separation negatives, i.e. R, G and B on separate films; *see* Sequential frame
THROW	Distance from a projector lens to the screen
TIME LAPSE	Film or video recording with a controlled delay between frames, to considerably speed up action
TIMER	US term for a grader (*see*)
TINT/TINTING/TINTED	Black and white print film coloured (tinted) by dyeing the film base or the gelatine with dye
TITLES	Words on screen, not part of the image, present for information to the viewer
TK	Colloquial term for a telecine machine or for telecine transfer of film to tape = (Tele-kine?)
TONE/COLOUR	Loose term for hue or perhaps saturation, or a combination
TONE/TONING/TONED	Print film in which the silver image is coloured by being replaced or augmented by a dye, another metal or metallic salt
TONE/SOUND	A single frequency
TONE CONTROL	Circuit for modifying the frequency response of amplifiers, effecting cuts in treble and/or bass
TONING BATH/TONER	An aqueous solution for toning black and white film
TRACK	A general term for an optical sound track, negative or positive

TRACK APPLICATOR	Device for applying a viscous developer solution in a bead or stripe to an optical sound track print
TRACK NEGATIVE	A film with a negative optical sound track only
TRAILER	A short advertising film for a feature film
TRANSPARENCY (1)	A still reversal print, or a still print for projection
TRANSPARENCY (2)	Degree of clarity in transmission of a material, converse of degree of diffusion
TRANSPARENCY FILM	A film stock, usually reversal, for the production of transparencies
TRAVELLING MATTE	A film special effect created by printing a foreground action from one source with background from another
TRICOLOR FILTERS	A set of three filters for exposing separation negatives or positives
TRIMS	Portions of scenes left behind after the utilized part is cut into a production
TRIPACK	A colour film with three separate R, G, B sensitive layers on a single base, sometimes called an integral tripack
TTL	'Through the lens', acronym for an exposure determination method
TUNGSTEN LIGHTING	Incandescent light source, originally using a tungsten filament; Type B lighting
TWO-COLOUR	A colour system using two analysis (and two synthesis) primary colours, additive or subtractive
TWO-STRIP	Two separate colour separation negatives, i.e. orange and green–blue on separate films
TYPE A	Refers to colour film balanced for 3400°K scene illumination
TYPE B	Refers to colour film balanced for 3200°K scene illumination
TYPE D	Refers to colour film balanced for 5400°K or similar scene illumination, equivalent to daylight
ULTRASONIC CLEANER	A device for cleaning film using ultrasonically induced cavitation in a solvent
ULTRAVIOLET	Wavelengths of light just shorter than the visible spectrum, immediately below blue
UN	Short form for Unissued; an unissued newsreel or similar
UNDER-CRANKED	A film run at less than normal speed, intentional or accidental
UNIDIRECTIONAL	In one directional only, usually referring to film printers
UNSQUEEZED	The process of displaying an anamorphic image in uncompressed form, by projection or printing
UP-AND-DOWN TRACKS	A photographic sound film with two tracks, one in one direction, one in the other
VARIABLE AREA TRACK	Uniform density optical film sound track in which the image width varies with the sound modulation
VARIABLE DENSITY TRACK	Uniform width optical film sound track in which the image density varies with the sound modulation
VAULT RATS	Restoration specialists who spent time in film vaults (USA)
VIEWFINDER	Optical device for viewing an image, on a camera or printer
VIGNETTE/VIGNETTING	An image in an oval or round diffuse surround
VINEGAR SYNDROME	Breakdown of cellulose acetate film base in time producing acetic acid
VISCOUS PROCESSING	Film processing using surface applied viscous solutions
VOICE OVER	A commentary or narrative to a programme, with unseen commentator
VOICE TRACK	Any sound track with voices, without other music or effects
VOLUME	Magnitude or level of sound
VTR	Video tape recorder
WALK THROUGH	A scene played though without filming; dry run (syn)

WEAVE	Side-to-side unsteadiness during film transport, in projection, printing or camera
WEDGE	A loose term for a stepped exposure sensitometric strip, sometimes a 'step wedge'
WET PRINTING	Contact or optical printing in which the original film is surface wet or immersed in solvent to reduce scratches
WHIP PAN	A pan (camera movement) in which the image is blurred and indistinct, sometimes a stock shot
WHITE	The visual appearance of a visible wavelength distribution, evoking a hueless sensation
WIDESCREEN	General term for any aspect ratio greater than Academy (1.33:1)
WILD SHOOTING	Picture shot without synchronized sound
WILD TRACK	Sound recorded without synchronized picture
WIPE	A scene transition where an image replaces another by a boundary moving across the frame
WORKPRINT	Cutting copy (syn); term used by editors
WRAPAROUND	The degree of any close contact of film or tape around a capstan, drum, sprocket wheel or other drive system
WRATTEN FILTER	A Kodak optical filter for camera or printer, known by individual numbers
X-AXIS	The horizontal axis of a graph
Y	The luminance component of a colour TV signal
Y-AXIS	The vertical axis of a graph
YELLOW	A subtractive primary
Z-AXIS	The other horizontal axis of a three-dimensional graph
ZERO-CUT	16 mm printing method using A and B rolls/checker-board cutting/splices not seen on print
ZOOM	The visual effect as a result of varying the focal length of a camera lens
ZOOM LENS	An optical system which changes magnification of an image

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http://www.ace1.nl

AFI – American Film Institute
http://www.afionline.org/preservation/preservation.home.html

AFRHC – Association Française de Recherche sur l'Histoire du Cinema
http://www.dsi.cnrs.fr/afrhc/afrhc.html

Agfa
http://www.agfa.com

AMIA – Association of Moving Image Archivists
http://www.amianet.org/

Archimedia
http://europa.eu.int/comm/dg10/avpolicy/media/en/archim/

BKSTS – British Kinematograph Sound and Television Society
http://www.bksts.com
Cinegraph – German Center for Cinema Research
http://www.cinegraph.de
Conservation On Line
http://palimpsest.stanford.edu
CST – Commission Supérieure Technique
http://www.cst.fr
DOMITOR – International Association Dedicated to the Study of Early Cinema
http://cri.histart.umontreal.ca/Domitor
ECAV – Cinematographic and Audiovisual Studies
http://www.imaginet.fr/secav/ressources/institutions/archives.html
FAOL – Film Archives On Line, GAMMA GROUP
http://www.faol.org/faol
FIAF – International Federation of Film Archives
http://www.cinema.ucla.edu/fiaf/default.html
FIAT/IFTA – International Federation of Television Archives
http://www.nbr.no/fiat/fiat.html
Fuji
htttp://www.fuji.com
George Eastman House – School of Preservation
http://www.eastman.org/film/filmpres.html
Haghefilm Laboratories
http://www.haghefilm.nl
IASA – International Association of Sound Archives
http://www.llgc.org.uk/iasa
Kodak
http://www.kodak.com
Nederlands Filmmuseum
http://www.filmmuseum.nl
NFPB – National Film Preservation Board
http://lcweb.loc.gov/film/
NFPF – National Film Preservation Foundation
http://www.filmpreservation.org/about.html
SMPTE – Society of Motion Picture and Television Engineers
http://www.smpte.org
Soho Images, London
http://www.sohoimages.com
UNESCO
http://www.unesco.org/webworld/en/highlights/audiovisual_archiving/philo1.html
University of New South Wales – Distance Education on film preservation
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