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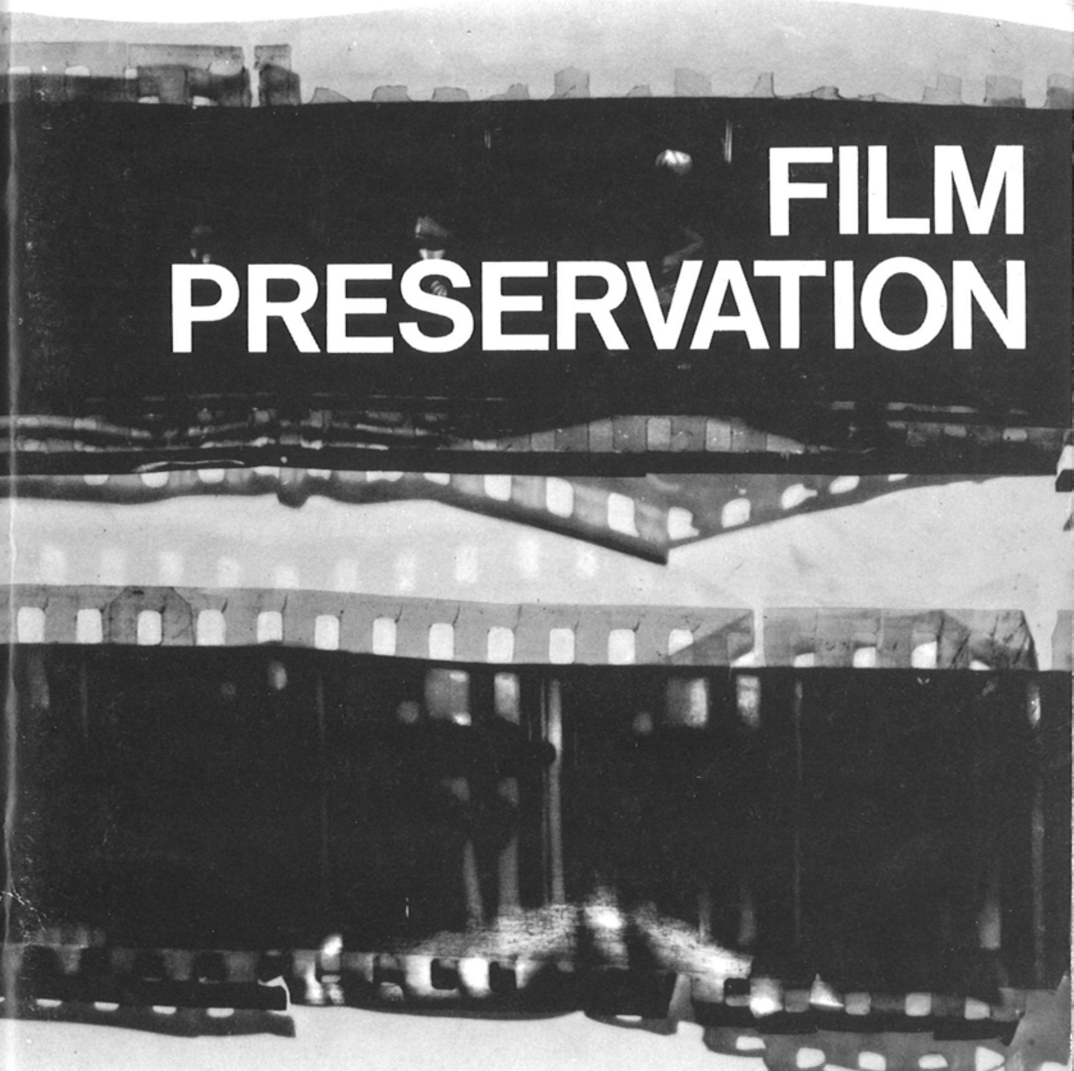

FILM PRESERVATION

A REPORT OF THE
INTERNATIONAL FEDERATION
OF FILM ARCHIVES

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A REPORT OF THE
PRESERVATION COMMITTEE
OF THE INTERNATIONAL
FEDERATION OF FILM ARCHIVES

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of the German Democratic Republic,
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PREFACE

The International Federation of Film Archives, realising that very valuable films in all parts of the world were being endangered by ignorance of the conditions necessary for their preservation, decided some years ago to set up an international Committee, with the purpose of collecting together all the known facts, and the results of all available experience, in the storing, preservation and restoration of cinematograph film, and to publish recommendations which could be put into practical use.

The directors and principal technicians of the following archives have co-operated disinterestedly in the work of this Committee, with the particular aim of helping newer and younger archives:

Cinémathèque Royale, Brussels	Belgium
Ceskoslovenska Filmoteka, Prague	Czechoslovakia
Danske Filmmuseum, Copenhagen	Denmark
Staatliches Filmarchiv der DDR, East Berlin	German Democratic Republic
National Film Archive, London	Great Britain
Stichting Nederlands Filmmuseum, Amsterdam	Holland
Magyar Filmtudomanyi Intezet es Filmarchiwum, Budapest	Hungary
Cineteca Nazionale, Rome	Italy
Norsk Filminstitutt, Oslo	Norway
Centralne Archiwum Filmowe, Warsawa	Poland
Gosfilmofond, Moscow	U.S.S.R.
Jugoslovenska Kinoteka, Belgrade	Yugoslavia

We are especially grateful to Mr. Ernest Lindgren in London, and to Mr. Victor Privato in Moscow, whose wealth of experience in this field has been a constant source of encouragement.

Thanks are also due to Mr. Dirk Huizinga in Amsterdam, Mr. Harold Brown and Mr. Ernest Lindgren in London for the translation of this edition.

This Report deals only with fundamental principles, and is intended to serve as a basic introduction to film preservation. Eventually the results of further research work, now being undertaken, will be incorporated so that it can be re-published as a manual for all film archives.

The Committee hopes that this Report will stimulate further discussion of the subject, and it will be grateful for any comments or additions which technical experts or others may be willing to supply.

All communications should be addressed to the Secretariat, F.I.A.F., 38 Avenue des Ternes, Paris 17e, France, or to myself (at the Staatliches Filmarchiv der DDR, Berlin W.8., Kronenstrasse 10, German Democratic Republic).

Herbert Volkmann

INTRODUCTION

The birth of the film is generally considered to date from the year 1895, the year in which, in various cities, the first film performances were given. It was not invented by any one man; many people of many nations participated in the development of this important invention, and its utilisation was likewise international. For nearly seventy years now, films have been produced in all the major countries of the world.

Never before had there been an art which reached so wide a public, nor such a possibility of influencing the thinking of mankind, nor any comparable prospect of transmitting to posterity such revealing historical documents. The film is one of the great achievements of the twentieth century.

During these seven decades many thousands of films have been produced; good and bad, excellent works of art and important documents as well as stupid rubbish or dangerous propaganda. From the very beginning there were people interested in collecting films, and everything concerning films, but many gradually abandoned their interest, much was lost in two world wars, much was deliberately destroyed and much was also lost by wrong treatment. As a result, it is no longer possible to show all the important productions of film history in a complete form on the screen. In many cases a title and a memory are all that exist; in others, only fragments or incomplete versions have survived, many in such a bad state that in their sad shadows one can hardly recognise the great works of art which once existed.

This lamentable deterioration is the consequence not only of human neglect but even more of the chemical properties of the film material itself, especially of nitrate film. Without a careful application of all the necessary rules for preservation, these properties could, within a few years, bring about the total loss of all the masterpieces of the first fifty years of film history. It is a cause for regret that there are already too many examples which prove this to be so.

Film archives are in the forefront of the movement now afoot to attempt to preserve this cultural heritage. More than forty film archives (under various names, including film museums, film libraries, cinémathèques, filmothèques, etc.) are grouped within the International Federation of Film Archives. They exist in the most important film-producing countries in all parts of the world, they are old and young, big and small, but they all have the common aim of doing everything possible to preserve films as documents and as masterpieces of film art both for their contemporaries and for the future.

There can today be no doubt that film archives are equal in cultural importance to the museums and galleries devoted to the plastic arts, and to the great libraries. They have the same task of protecting great works of art and important documents from damage or loss in order to make them accessible for research workers and for the general public; and, in the same way, they can only perform this task if they work without commercial aims and with adequate subsidies.

This report will deal with all the complications of preserving cinematograph film for long periods, but before all else we must emphasise the fact that it is impossible to preserve films without spending money. It is self-evident that every government has the duty of preserving national works of cultural value for future generations, and it is high time that important films, considered both as works of art and as documents, should be included among these national productions of cultural value which demand to be preserved.

It is not accidental that the richest film archives of the world are state institutions, or at least institutions supported by considerable state subsidies. Film archives which exist on a more or less private basis, backed by a small group of film friends but without any other means of support, may carry on desperate struggles for the preservation of their film treasures; the struggle deserves every praise, but its results are extremely uncertain. It is regrettable that, in many countries, the film is regarded as exclusively a private commercial business, and not as a cultural asset in the preservation of which the public interest should have priority. In countries where film production is organised by the state, film preservation is well provided for, but elsewhere one of the first tasks of film archives is to combat public indifference, to make clear the necessity of a state subsidy and to demand it.

The triumphal rise of television does not change these facts in the least. Many of the larger film archives have already begun, in addition to collecting and preserving film productions, to do the same for television productions. Outside the commercial sphere, there is no opposition of interests between film and television. The best works in both have the same kind of cultural value, the preservation of which is in the national interest. Television, with its new techniques, has simply made the task of film archives more extensive and complicated.

Film archives may collect not only films, but also all kinds of objects related to films, such as documents, designs, apparatus, etc. This Report, however, will deal only with the problems of storing, preserving and renovating cinematograph films, since these constitute the most important and most difficult task of any film archive.

1. OPTICAL CINEMATOGRAPH FILM AND ITS PROPERTIES

STRUCTURE OF CINEMATOGRAPH FILM

1.1 The material with which we are here concerned is developed cinematograph film, mainly of 35mm or 16mm gauge. From the beginning of film production, this has consisted of the same elements: a transparent base or support and one or more coatings which are made to adhere to it by means of an adhesive substratum. Sometimes the outside of the base is covered by a thin layer of varnish, to prevent the film from curling.

Film Base

1.11 The film base or support consists chiefly of nitro-cellulose (nitrate film) or of acetyl-cellulose (acetate, or safety film). The two bases look exactly alike, have similar optical qualities, and equal elasticity and toughness. Because of their different chemical properties, however, they differ in their length of life, their inflammability and the influence they can exercise on their surroundings.

Emulsion

1.12 The emulsion for the optical recording of both picture and sound is in principle the same for all black-and-white film, both positive and negative. It consists of a suspension of silver salts in gelatin. For colour films, the emulsion is also composed of gelatin and silver salts, but chemical colour-forming substances are added. Black-and-white films never have more than one emulsion layer. Colour films may have either one (as in Technicolor) or more than one: for example, there was a process, now obsolete, which had a layer on each side of the base; such processes as Agfacolor and Eastmancolor employ three layers on one side of the base (one for cyan, one for magenta and one for yellow). This means that, for the preservation of the emulsion, all makes of black-and-white film in normal use require the same storage conditions, and that in the case of colour films it is only the colour elements which may require other conditions.

Adhesive Substratum

1.13 The adhesive substratum consists of gelatin.

Varnish Layer

1.14 The varnish layer consists of a solution of 1% nitro- or acetyl-cellulose, according to the base.

NITRATE BASE

1.2 Until 1950, nitrate base was used almost exclusively for 35mm cinematograph film (both black-and-white and colour). Other widths (16mm and 70mm) and magnetic films were made on acetate base. To-day, all cinematograph film is made on acetate base (safety base).

Composition

1.21 In the manufacture of nitrate base, a cellulose ester is treated with nitric acid to produce cellulose nitrate. Organic plasticisers are added to eliminate brittleness.

Properties The base made in this way has good optical and physical properties, but also two most undesirable characteristics which play a decisive part in the technique of its storage: 1.22

(i) These nitrogen compounds are very unstable. With the passage of time the nitrate groups dissociate, and even under the most favourable conditions nitrate film decomposes.

(ii) Like all substances of this group, which are closely related to the explosive nitro-cellulose (gun-cotton), the nitrate base is highly inflammable. It ignites very easily (in the case of new nitrate film at about 130°C, 266°F), and burns very quickly, indeed (in large quantities) explosively: 20 tons of film, equivalent to 8000 reels of 1000 feet each, can burn out within three minutes.

Disintegration of Nitrate Film Nitrate film begins to decompose from the moment its production is completed. This disintegration is slow, but no means has yet been found of checking it. In the course of decomposition, the film releases gases, principally compounds of nitrogen and oxygen, of which nitrogen peroxide (NO_2) is particularly harmful. In combination with the moisture content of the gelatin, it forms nitrous acid (HNO_2) or nitric acid (HNO_3). These acids bleach the silver image in the emulsion and accelerate the decomposition of the base to the point of complete destruction. The nitrate gases will have the same destructive effect on all films stored in the same room, whatever their age, whether they are nitrate or acetate. 1.221

In good storage conditions, this decomposition proceeds very slowly and may take many years. For a long time the film shows no external signs of disintegration. Only in the final stages, which may last no more than a few months before the final destruction of the film, does the decomposition of nitrate film visibly manifest itself in the following sequence of physical changes:

(i) the silver image undergoes a brownish discoloration and fading.

(ii) the emulsion becomes sticky.

(iii) there is a partial softening of the reel of film (formation of "honey"). the appearance of blisters, and a pungent smell.

(iv) the entire film congeals into one solid mass.

(v) the film base disintegrates into a brownish powder giving off an acrid odour. In this last stage the film has a very low ignition temperature and is highly explosive.

In the first and second of these stages the film can still be saved by immediate treatment (see 7) and by copying; in the third stage it may be possible to save it partially; when it reaches the fourth and fifth stages, however, it is irretrievably lost and must be destroyed at once.

It is of the greatest importance that the stage of disintegration of nitrate film can fortunately be determined by a chemical test, the film stability test (see 6.14), before any observable physical changes become apparent.

Given these circumstances, what is the life expectancy of an exposed nitrate film? This cannot be indicated in precise terms because it depends on a number of factors, notably:

the purity of the materials used in the production of the raw film;

the care taken in processing, and in particular the thoroughness with which the developed and fixed film is washed and rinsed;

the conditions in which the film was stored before it came into the possession of the archive;

the conditions of storage in the archive itself.

We know that some films which were made in the earliest days of the cinema, and which are now over 60 years old, have been preserved and are still in quite good condition. On the other hand, we also know of films which have been kept under bad conditions and have completely decomposed within ten years of manufacture. All that we can say for certain is that the great majority of nitrate films now being stored in archives have already reached a dangerous age and should therefore be treated with the greatest caution.

1.222 When a film is stored in conditions which are too dry, the plasticisers and the moisture in the emulsion evaporate. The film shrinks, and the distance between the perforations changes, leading to possible damage of the perforations during projection or copying. Shrinkage may become so marked that the film can no longer be projected or copied on normal apparatus. Ultimately, it will become brittle and useless. At a relatively early stage, humidifying in a filmostat (see 7.35) may help, but any recovery of flexibility will last only for a short time. It is impossible to reverse the shrinkage. *Shrinkage*

1.223 As already mentioned, nitrate film is extremely inflammable. New raw stock has an ignition temperature of about 130° C (266° F). As disintegration proceeds, the ignition temperature of the film falls, and eventually it may spontaneously ignite at relatively low temperatures. It then burns very quickly (20 tons of film in three minutes), when temperatures of 1700° C (3060° F) may be reached. There is no known means of extinguishing the fire of burning nitrate film. As it produces its own oxygen, it will continue burning under water or under carbonic acid snow. *Inflammability*

Laboratory tests carried out in the U.S.A. in 1949 have established that nitrate film may ignite spontaneously at temperatures of 41°C (105° F), not far from the high temperatures to be found in even temperate climatic zones. As the number of tests carried out has been relatively small, it is conceivable that nitrate film in the final stage of disintegration may spontaneously ignite at even lower temperatures. The same tests also established that new nitrate film is not inclined to spontaneous combustion at such low temperatures; therefore, not only does ageing result in increasing disintegration, but also in a growing inclination to spontaneous combustion. This could explain the several film archive fires which have occurred in recent years in countries with such different climates as Brazil, France and Finland. In these cases very valuable, and sometimes irreplaceable, film has been destroyed. It would be disastrous to remain blind to this danger, and not to ensure the best storage conditions, and duplication on safety film as soon as possible.

1.23 *Requirements for Preserving Nitrate Film*

1.231 The process of disintegration must be retarded. Since chemical reaction becomes slower as the temperature falls, the first requirement is to store nitrate films at the lowest possible temperatures. The most suitable temperature is 2° C±2° (35° F±3°). Even in archives which have no air-conditioning installation, temperatures must be kept as low as possible. Reducing the storage temperature by 5° C has the effect of reducing by one-half the rate at which the nitrate base releases nitrate gases; this also means that the concentration of the nitric acids is retarded, which in turn slows down the disintegration process.

Humidity accelerates the disintegration caused by nitrate gases. The greater the amount of moisture from which nitrous acids can be produced, the more quickly disintegration proceeds. On the other hand, too dry an atmosphere induces shrinkage and brittleness, as we have seen (1.222). Films, therefore, have to be stored in such conditions of humidity as to retard the disintegration process, while at the same time preventing shrinkage and brittleness. The extremes for each requirement do not lie far from each other; the most favourable relative humidity is between 40 and 60 per cent.

In order to reduce the harmful effects of the small amounts of nitrate gases 1.232
which will be released even at low temperatures, it is necessary to provide good ventilation. It follows from this that nitrate films must never be stored in airtight cans.

Nitrate film must be stored in such a way that every danger to itself and its 1.233
surroundings is eliminated as far as possible. In most countries there are statutory regulations governing the storage of film which film archives must in their own interest observe most punctiliously. On no account should nitrate films be stored in buildings where living or working quarters are housed. Excessive amounts of film should not be present in laboratories and examination rooms. Sufficient emergency exits must be provided, as well as fire fighting appliances (hand foam extinguishers and fireproof covers).

When outward signs of disintegration become visible, or when the film 1.234
stability test reveals an advanced stage of disintegration, the nitrate film, if its content is to be preserved, must be duplicated on to acetate film as soon as possible. After duplication, the disintegrating nitrate original must be destroyed. There is no alternative course, since the best storage conditions can only retard disintegration, not stop or reverse it.

When it is not possible to duplicate the film immediately, it must be separated from the rest of the films being stored, in order to avoid endangering them.

If an archive is unable to have the film copied for financial or other reasons, and believes that no other copy, or no copy as complete or as good technically, exists elsewhere, it should ask other archives (members of FIAF may do so by way of the Secretariat of FIAF) if they are willing and able to duplicate the film. There is little question that there will always be an archive ready to do this. Presumably the duplicating would have to be done in the country where it has been stored, since it would be irresponsible to entrust a film in such a state of disintegration to a public transport service, and any other means of transport over long distances would be extremely expensive.

ACETATE BASE 1.3

Composition

Acetate base has a composition different from that of nitrate base, and there- 1.31
fore different chemical properties. Its raw material is also cellulose, but it is esterified not with nitric acid, but with acetic acid, so as to form cellulose acetate (also called acetyl cellulose). To this, too, plasticisers have to be added.

During the development of safety film, stocks were manufactured with bases of acetate-butyrate and acetate-propionate. To-day most safety film is produced with a base of tri-acetate. All these films have practically the same properties as far as permanent storage is concerned, so that for archive practice we can regard all films on acetate base as a unit. For archive purposes it is important to note that practically all 16mm films, all 70mm films, all magnetic films and tapes, and since 1950 nearly all 35mm films, have been manufactured on acetate base.

Properties

1.32 Acetate film is relatively young, and research on it is still at an experimental stage. There is much that cannot be said about it for certain, but there is no doubt that the physical and biological properties of acetate base are as good as those of nitrate base, and that it has, moreover, two great advantages:

1.321 (i) Acetic acid compounds are much more stable than nitrate compounds. A separation of acetic acid takes place, similar to the breakdown of cellulose nitrate, but it proceeds very slowly, and decomposition phenomena proper have not yet been observed. For purposes of archive storage, therefore, acetate film has a far longer life than nitrate film. Tests carried out in the USA on the same principles as the research into paper (artificial ageing by heating in an oven) have confirmed that acetate film is far more stable than nitrate film, and that in good storage conditions it may be expected to have a life-span of 200-300 years. Also, it does not exert a harmful influence on other films in its vicinity.

1.322 (ii) Acetate film is no more inflammable than paper. It is not susceptible to spontaneous combustion, and only ignites with difficulty. In small quantities it does not burn at all, but simply smoulders.

1.323 For purposes of permanent storage it is important to know that, when acetate film is stored in conditions which are too dry, its plasticiser escapes under the influence of atmospheric oxygen, so that in due course the film shrinks and becomes brittle. When humidity is too great, the plasticiser crystallises out.

1.324 The chemical influence of acid gases in the air, especially those produced by the disintegration of nitrate film, is injurious to the preservation of acetate film.

1.33 *Requirements for Preserving Acetate Film*

1.331 Since acetate film carries no fire risk and is not dangerous to its surroundings, it is not necessary to take greater fire precautions in respect of it than are usual in ordinary libraries. This, of course, influences the construction of the buildings in which it is to be stored.

1.332 Since acetate base does not generate injurious gases and does not produce any symptoms of disintegration, it does not require to be cooled to the same degree as nitrate film, nor to be ventilated in the same way.

The emulsion, on the other hand, is the same as that of nitrate film, and in order to avoid the formation of fungus (see 1.422), low storage temperatures are desirable, In any case, the temperature and the moisture of the air (which should not exceed 60 per cent. relative humidity) ought to be kept constant.

1.333 The chief hazard to the durability of acetate film is that the plasticiser tends to escape from the base, so as to leave the film hard and brittle and no longer capable of being projected. It would seem that this danger can be averted by airtight storage. In some archives, in fact, it is the practice to insert acetate films into airtight plastic bags before placing them in their cans. This may introduce another danger, however: water condensation on the film as a result of a change in temperature. As is well known, when temperature falls the moisture in the air condenses in the form of water, and this will occur even inside a closed container. If this were to happen to a film without being immediately noticed, and the film subsequently became dry again, the result would most probably be irreparable damage.

Therefore, films should only be stored in airtight containers when:

(a) they can be kept and slowly rewound for several hours before packing in a room which has the same temperature and relative humidity as the store in which they are to be placed.

(b) constant temperature and relative humidity can be guaranteed within the store, and also while the films are being conveyed to the store. They should be moved as little as possible, although of course they must be subjected to periodical examination.

This method of storing is only advisable for material which is to be stored permanently with the guarantee that atmospheric changes can be avoided.

As the nitrate gases which are released during the decomposition of nitrate film have a most destructive effect on acetate film, one of the first requirements for the preservation of acetate film is that it shall be stored quite separately from nitrate film. 1.334

EMULSION LAYER FOR RECORDING PICTURE AND SOUND

Cinematograph film and magnetic tape have (for the purposes we are considering here) no value in themselves; they are simply a means for the retention and reproduction of pictures and sounds. Therefore, the layer on which picture and sound are recorded is the most important of the several of which the film consists. It is only because the physical properties of this emulsion layer, and especially its extreme fragility, are not equal to the stresses imposed on it in passing through the apparatus used in recording, processing and reproduction, that the other layers of the film, and particularly the base, are indispensable. 1.4

We can distinguish two kinds of recording layer:

(i) light-sensitive layers, for pictures in black-and-white and in colour, and for optically-recorded sound.

(ii) magnetic layer on cinematograph film for magnetic sound.

Construction of the Light-Sensitive Layer

The light-sensitive emulsion of black-and-white film consists of silver bromide or silver chloride crystals, very finely divided and suspended in gelatin. Colour film has, in principle, a similar emulsion, to which chemical colour-forming substances have been added. 1.41

Gelatin and its Properties

Gelatin is an organic product (animal albumen, made by boiling bones and hide-offal in diluted acids). Tests have shown that given good storage conditions which are not too moist, it is almost as durable as the base. 1.42

Gelatin, however, very readily absorbs moisture, and then swells and becomes sticky. This very dangerous development, which can lead to the complete destruction of the image, is assisted by warmth. 1.421

Furthermore, gelatin is an almost ideal nutrient for fungus. Fungus spores are always in the air and when they encounter favourable growing conditions (moisture and warmth) they develop rapidly. The fungus which appears on emulsion and base nearly always looks like white, greenish or grey fur. The fungus penetrates into the layer, and if it is not stopped, the image is consumed, colours are changed, and finally the emulsion is completely destroyed. 1.422

This damage can only be avoided if the humidity in the film store is constantly controlled (the relative humidity should not exceed 60%) and if temperatures are constantly kept at a low level. It must be pointed out, however, that there is a limit below which humidity should not be reduced. Films which are stored in too dry conditions shrink considerably and become brittle (see 1.222). As a result, they can no longer be projected or copied and have therefore lost their value. Except at extremely low temperatures (less than —5°C, 23°F), films can only be stored without damage for extensive periods at a relative humidity of 50–60%.

1.43 *The Black-and-White Image*

1.431 The photographic black-and-white image in the developed emulsion consists of finely divided blackened metallic silver. If carefully treated it is very durable but it has to be protected against chemical influences.

1.432 The first requirement for its preservation is a thorough fixing and washing after the development of the film. If the chemicals used in development are allowed to remain in the film, they continue to act after it has been dried and cause spottiness, discolouration and bleaching of the image.

1.433 Furthermore, the products of disintegration of the nitrate base are as dangerous to the silver image as they are to the complete film (see 1.221). The nitric acids which form during the progress of disintegration bleach the silver image, decompose the gelatin, and finally attack the base, regardless of whether it is a nitrate film, or an acetate film stored in the same room.

1.434 In the same way, acid gases and other pollutions in the air (for example, sulphurated hydrogen and sulphur dioxide), which are freely produced in large quantities by the burning of coal, particularly in industrial areas and big cities, can have a very detrimental influence and over a period of time they can amount to a serious danger to the preservation of film.

1.435 Of course, the growth of fungus on the gelatin (see 1.422) does not leave the silver image unaffected; parts of the image shift, distortions occur, and finally the layer disappears.

1.44 *The Coloured Image*

1.441 The photographic coloured image which is produced by the colour-forming substances during the process of development, is considerably less durable than the black-and-white image. Its preservation can be extended only with great difficulty. In the long run the whole image will eventually bleach, although usually the colours do not fade simultaneously, but one after another. However, it is sufficient for only one colour to disappear for the film to lose its original value.

1.442 The colours fade most rapidly when the temperature and moisture of the air are too high. The producers of raw film do not seem to be in agreement concerning the storage properties of colour films. Agfa-Wolfen maintains that the standards of temperature and humidity required for permanent storage of the base are adequate.

Eastman-Kodak recommends for the storage of Eastman-Color and Kodachrome films a temperature of —18°C (0°F) and a relative humidity of 15–25%. It is, of course, very expensive to maintain such low temperatures for permanent storage. Moreover, films which are stored in this way have to be warmed very slowly and carefully before they can be rewound and projected at normal temperatures. Kodak states that 60 hours are needed to warm a 35mm full-length feature film copy from —18°C (0°F) to 20°C (68°F). This is also necessary to avoid any condensation of water. 1.443

Light can also be a destructive influence on the colour image. However, as films in permanent storage are always enclosed in cans in a dark vault, this danger is not great. 1.444

Acid gases in the air have the same damaging effects on the coloured image as on the black-and-white image.

There is only one quite certain method of preserving colour films: namely to make of each of the three basic colour images used in the film (yellow, magenta and cyan) a black-and-white separation print, and to store these three prints in the same way as normal black-and-white acetate film. From these separations a negative in the original colours can be made at any time. This method is not cheap, but it is safer and cheaper than trying to store films in their original colours. 1.445

The cheapest way to save a colour film from complete destruction is to make from it a simple black-and-white copy and to store this. But this method is also the least satisfying, because it results in the loss of one of the essential characteristics of the film, the colour. 1.446

Sound Tracks 1.45

The optical sound track of cinematograph film is recorded on the same light-sensitive layer as the picture. Therefore everything which has been said about the photographic emulsion and the base also applies to the sound track. 1.451

For cinematograph films with a magnetic sound track, the same rules as for emulsion and base, together with the rules for magnetic sound-recording (see 2.4), have to be followed. 1.452

Requirements for Preserving Light-Sensitive Layer 1.46

For the preservation of the emulsion, black-and-white film should be stored at not too high a temperature and with constant control of the humidity. The relative humidity should be between 50% and 60%. 1.461

Destructive chemical influences (the disintegration products of nitrate film, pollution of the air) should be warded off by adequate ventilation and by filtration of the air. 1.462

Film copies in colour should not be permanently stored, because of the difficulties of preserving the original colours. Instead, separations on black-and-white film should be made and preserved. 1.463

2. MAGNETIC FILM AND MAGNETIC TAPE

COMPOSITION

2.1 In addition to cinematograph films with a light-sensitive layer, we may also have to store films and tape for the magnetic recording and reproduction of sound and image, which are used especially in television. The great development of television throughout the world has already obliged many film archives to undertake the preservation of television programmes of exceptional quality, and this makes it necessary for us to consider the problems to which this gives rise.

In principle, the constitution of magnetic materials for the recording of sounds and pictures is similar to that of cinematograph film: either a base of cellulose acetate (as used for safety-film) coated with a layer of lacquer in which very finely divided iron oxide powder is suspended, or a synthetic base (mostly Polyvinylchloride) with the magnetic particles suspended in the body of the material.

KINDS OF MAGNETIC RECORDING MATERIAL

2.2 The following kinds of magnetic recording material are to be distinguished:

- Optical picture film, with magnetic sound-track (COMMAG)—35mm and 16mm.
- Magnetic sound-recording film (SEPMAG)—35mm, 17·5mm and 16mm.
- Magnetic sound tape—6·25mm.
- Magnetic picture tape (Videotape)—50mm and 25mm.

Optical Picture Film, with Magnetic Sound-track

2.21 This is normally perforated cinematograph film on acetate base, 35mm or 16mm wide, carrying one or more magnetic sound-tracks. The magnetic track is put on in the processing laboratory along the length of the film (as far as one track is concerned), in a position corresponding to that of the sound-track on an optical film, but on the celluloid surface, not on the emulsion surface.

Not more than one magnetic sound-track is put on to 16mm film, but 35mm film normally has either one or four (four-channel magnetic sound).

Magnetic Film for Sound-Recording

2.22 This consists of a perforated base of cellulose acetate, 35mm, 17·5mm or 16mm in width having no light-sensitive layer, but coated with a cellulose lacquer carrying very finely-divided magnetic oxide. The recording is registered lengthwise along the tape.

Magnetic Tape

2.23 Magnetic sound tape, 6·25mm in width, is a non-perforated tape, manufactured from Polyvinylchloride, in the body of which finely-divided magnetic oxide is suspended. It records sound lengthwise along the tape.

Magnetic Picture-Tape Magnetic picture tape, 25mm or 50mm wide (Videotape), is a non-perforated tape made of Polyvinylchloride coated with a lacquer in which the iron-oxide powder is suspended. The magnetic tracks run transversely across the width of the film, and in this way a magnetic track 40 metres in length can be recorded on 39 cm of tape. On the upper edge a magnetic sound-track runs and records lengthwise. At present, tape of this kind is used only in television. 2.24

PROPERTIES OF MAGNETIC RECORDING MATERIALS 2.3

The base of magnetic films, being the same as that of safety-film (celluose acetate), is subject to the same standards, as set out in 1.3 above. 2.31

The base of magnetic tape consists of Polyvinylchloride, and is not transparent, because it is never used for optical recording and projection. Its physical and chemical properties make it a very suitable material for permanent storage.

Magnetic material has the great advantage that recordings can be reproduced from the same tape, directly after the initial recording, without the time-wasting complications of developing, fixing, washing, drying and printing necessary for cinematograph film. 2.32

These and other advantages, including excellence of reproduction, are offset, however, by some adverse characteristics which have an important bearing on preservation. 2.33

As all magnetic recordings are magnetised fields, they can be changed by external magnetic forces. Picture and sound can be distorted, and even partly or wholly erased. So far science has found no way of fixing magnetic picture and sound records.

A conference of technical experts, called together by the British National Film Archive in London to consider the problem of preserving magnetic recordings, has expressed the opinion that magnetic tape recordings have an indefinite life provided they are stored subject to certain conditions, one of these conditions being that the tapes are not reproduced, since every reproduction involves the danger of disturbance to the recording, and deformation of the image and sound, and repeated reproductions may quickly render the image quite useless. It would be absurd to keep tapes simply for the sake of storing them.

This is not the only danger. All sources of magnetic force in the immediate vicinity of magnetic tape recordings are dangerous, especially direct-current motors. The shortest safety-distance is 4 metres (13 ft.). If magnetic films and tapes are placed any closer to a source of magnetic force, they are likely to be erased, so that the recordings vanish completely.

Also the so-called copying effect (known also as " ghosting ", " print-through " or " seepage ") causes difficulties. This is the effect which 2.34

each layer or turn in a roll of magnetic tape exerts on the layers adjacent to it, so that its recording is copied faintly on to them. The high frequencies, which magnetically extend wider than the lower ones, are particularly subject to this effect and can cause disturbing distortions Although one hears it said that this effect occurred only when magnetic recording was at the beginning of its development, it is as well to be warned of it. What is certain is that high temperatures (over 18°C, 64°F) favour the occurrence of this copying effect.

2.4 REQUIREMENTS FOR PRESERVING MAGNETIC RECORDINGS

2.41 For the base of magnetic films and tapes the same requirements are applicable as have already been mentioned in **1.331** and **1.332** for the acetate base. The material presents a low fire hazard and is not liable to disintegration. A PVC base is chemically even more stable than an acetate one. As developing, fixing and washing are not required for magnetic recordings, there are no difficulties arising from the residues of harmful chemicals.

2.42 The greatest problem in the archive preservation of magnetic recordings is that they cannot be fixed. So far no way has been found of keeping the iron oxide particles irreversibly in the state in which the process of magnetising has arranged them, the only way which guarantees the correct reproduction of image and sound free from any distortions. This makes it necessary to prevent any magnetic field from coming into the vicinity of tapes being stored, and to ensure that outside influences cannot alter the pattern in which the magnetic particles have arranged themselves during recording.

2.421 The danger of demagnetising is present wherever electrical apparatus with direct current motors is used. Stores in which magnetic films and tapes (or cinematograph films with magnetic sound tracks) are kept should not have lifts or hoists driven by direct current. Tapes should not be transported by electric cars or tramcars. Vacuum cleaners and dehumidifiers are both sources of danger.

2.422 In storing magnetic films and tapes, wooden racks should be used and not steel ones, since the latter can conduct magnetic impulses. Tapes and films should be stored in steel cans to protect them from the influence of external magnetic fields.

2.423 The Committee of technical experts convened by the British National Film Archive, which was concerned particularly with the problems of storing Videotape recordings of television programmes, i.e. picture and sound recordings on 50mm magnetic tape, stated that the permanent preservation of such tapes without loss of quality could only be absolutely guaranteed if they were not played. It was therefore suggested that archives might consider keeping two tapes, one for reproduction and one to be kept exclusively for the purpose of making a new tape for reproduction when the first one had become useless.

This, however, presents economic difficulties, since the reproduction of Videotapes requires very complicated and expensive apparatus and qualified technicians. As the magnetic recording of pictures is only at the beginning of its development, it is possible that this expensive apparatus might become obsolete within a relatively short time, and be of interest only to museums. It is also possible that such apparatus can become out-of-date for other reasons, for example as the result of international agreement concerning the line frequency of the television image.

The English Committee therefore came to the conclusion that the most practical method of preserving works of art or historical documents recorded on Videotape was to copy them in the form of an optical film negative on 35mm acetate film. This method has already been used for a considerable time by broadcasting companies for their own archives. This means that film archives should not be concerned so much with the preservation of magnetic tapes, as with duplicating them on optical film. In cases where an archive is obliged to accept magnetic recordings of picture and sound, it is highly advisable that such recordings should not, if possible, be released for reproduction before an optical film negative has been made from them. Magnetic sound tapes for films supplied with magnetic sound should be stored together with the optical picture negative and, whenever necessary, combined projection copies can be made.

In considering the consequence of print-through (see 2.34 above), we 2.424
pointed out that the tendency towards print-through was greater when the temperature of storage conditions was high. The Government Broadcasting Committee of the German Democratic Republic recommends a temperature of 6°C (42°F) as the most favourable for the storing of magnetic recordings.

3. SOME GENERAL CONCLUSIONS

3.1 In storage, it is absolutely necessary to separate nitrate film from acetate film, since the nitrate gases given off by nitrate films in the course of disintegration can adversely affect any acetate films stored with them. SEPARATING NITRATE AND ACETATE

3.2 Because of its tendency to spontaneous combustion, and in order to slow down its chemical disintegration, nitrate film should be stored at as low a temperature as possible, at a low relative humidity, and with good ventilation. The store should be divided into small fireproof compartments. STORAGE ATMOSPHERE FOR NITRATE FILM

3.3 Acetate film need not be stored at such low temperatures as nitrate film, but, for the preservation of the emulsion, storage in relatively cool conditions is desirable. Acetate film can be stored in large rooms, without greater fire precautions than are required for large libraries. Normal ventilation is sufficient. STORAGE ATMOSPHERE FOR ACETATE FILM

3.4 Nitrate film and acetate film react quite differently to air-tight storage. When nitrate film is hermetically sealed, the nitrate gases which it constantly produces have no means of escape. They combine with the natural moisture of the gelatin to form nitric acids, which bleach the photographic image and accelerate the process of disintegration, even in the best possible climatic conditions. This appreciably shortens the duration of life of the nitrate film. In no circumstances, therefore, should nitrate films be stored in airtight conditions (e.g. sealed in plastic bags or non-porous waxed paper, kept in tins sealed with adhesive tape, etc.). On the contrary, the greatest care must always be taken to see that the air in the cans and in the store is constantly replaced. VENTILATION

Acetate film does not release dangerous gases, and ventilation is less critical. In fact, since the plasticisers, which are necessary to keep the film supple, tend to escape, acetate films may be hermetically sealed to preserve the plasticisers, provided the storage temperature is kept constant to avoid condensation (see 1.333).

3.5 To attempt to preserve colour films in the form of coloured copies is not effective. To preserve the colours, separations on black-and-white acetate film should be made whenever possible. These can be preserved in the same way as other acetate films. If an archive is obliged to store coloured copies, however, then low constant temperatures are desirable. PRESERVING COLOUR FILMS

MAGNETIC FILMS AND TAPES Magnetic films and tapes should be stored in the same way as acetate films, taking particular care against loss or distortion of the non-fixable magnetic recordings. 3.6

ONLY TWO TYPES OF STORE REQUIRED It follows from this summary of conclusions that in principle only two types of store are needed: one for nitrate film and the other for acetate film. 3.7

SOLUTIONS, TEMPORARY AND LASTING In the sections which follow, these findings will be applied to film archive practice. As much advice as possible will be given on how to achieve reasonable conditions with modest means, having regard to the fact that younger film archives, in particular, may not be able immediately to establish ideal conditions, which are necessarily rather expensive. Most of them, however, can only be temporary solutions. 3.8

When one considers on the one hand the vulnerability of the material we have to preserve, and on the other its high value as a form of artistic and historical record, the best and most expensive measures of preservation are still in the long run the cheapest.

4. STORAGE PROBLEMS AND CONDITIONS

4.1 **STORAGE PROBLEMS**

4.11 *Differences of Climate*

Although the most favourable storage conditions for cinematograph films and magnetic tapes are determined by the properties of the materials of which they are composed, and are therefore the same for every part of the world, the attainment of these conditions naturally presents difficulties which differ from archive to archive.

One of the first conditions for the preservation of film material is that it should be stored in a relatively cool, and not too moist, atmosphere. Undoubtedly it is more difficult and expensive to create good storage conditions in tropical regions than in temperate ones. In any case, and particularly under bad climatic conditions, no stores should be built in damp surroundings.

Dry ground, dry surroundings, natural or artificial shade and clear air are primary requirements for the creation of good storage conditions. They will have to be supplemented by technical devices designed to complement, and improve on, local climatic conditions.

4.12 *Economic Limitations*

The differences which exist between the material resources of film archives result in a wide diversity of practice. It has already been emphasised in our Introduction that to preserve the classics of film art, just as much as to preserve other cultural works, considerable financial expenditures are necessary, a fact unfortunately not yet recognised by all countries. Because of the specific properties of film materials, however, their permanent preservation demands the building of suitable stores, the maintenance of given levels of temperature and humidity, regular inspection of the film copies and the possibility of making new copies, to mention only the most important requirements.

In favourable conditions improvisation is possible for a short time, but the danger here is that it may be carried on for too long, in which case an effort which began with the best of intentions will end with material being lost as the result of inadequate storage conditions and care.

4.13 *Archival Storage and Projection Copy Storage*

4.131 *Archival Storage*

The archival storage of films is permanent storage, having as its sole object the preservation of the film. To this everything else is subordinate. The film is stored under the best possible conditions, and is only brought out of the store and rewound at predetermined intervals in order to check its preservation condition. In principle, negatives or duplicating prints should be preferred for this kind of storage, although used projection copies of films no longer in commercial distribution may have to be accepted, particularly where these are unique copies of films existing in no other form, either in the country concerned or in the world at large. It would be irresponsible, however, not to duplicate a film of this kind immediately, so that it no longer exists in the form of a single copy only. Failing this, unique copies, even if they are positive projection prints, must be treated as master copies, and be handled with special care; they should not be made available for exhibition.

Storage of Projection Copies

4.132 All film archives have a duty to make their treasures accessible to those who wish to study them by making them available for educational non-commercial viewing. For this purpose copies should be used which are designated as projection copies, and which can be reprinted, when they are worn out or damaged or lost, from the original material in the possession of the archive. The value of a copy used for exhibition diminishes with every projection. Not only does it suffer mechanical damage (tearing of the perforations, scratches, etc.), but also, while it is held in the projection gate, the film is exposed for short periods to high temperatures and this, together with the warmth generated by the sliding of the perforated margins over the metal gate runners, contributes to the drying and brittleness of the film. In considering the storage of projection copies, it should be noted that, because they are constantly exposed to this process of wear and tear, they never become so old that ageing problems have to be reckoned with. Storage is therefore a simple and uncomplicated keeping of the film in ordinary climatic conditions, without any intention of permanent preservation.

Separation of Archival Storage and Projection Copy Storage

4.133 It is urgently recommended that projection copies are kept quite separate from film material being stored for archival purposes, for the following reasons:

(i) So that archive copies cannot in error be used as projection copies, which would result in a loss of their quality.

(ii) Projection copies are subjected to considerable differences in temperature and humidity during transport and showing. If such copies were intermittently stored for short periods in archive conditions these differences would be greatly intensified, because the conditions of ideal archive storage differ greatly from the climatic conditions of the outside world. Furthermore, since storage compartments designed for permanent preservation are maintained at very low temperatures, many hours would be required for warming or cooling the copies. Where projection copies have to be stored for long periods of non-use, keeping under archive conditions is, of course, to be recommended, but always separate from the archive copies.

For these reasons it is recommended that copies which are in constant movement should be kept in stores without any air conditioning, but which are protected from excessively high temperatures by suitable insulation.

4.14 *Separate Storage for Safety*

4.141 The total loss of many important films in archive fires during the last decade makes it necessary to consider how the collection of a film archive can be safeguarded against all accidents. Adequate precautions against fire and the provision of fire-extinguishing equipment are normal for any film archive, but in exceptional cases, particularly when nitrate film produces spontaneous combustion, they can fail. The only guarantee against a total loss by fire is to store two copies of the same film (e.g. positive and negative) in different stores situated so far from each other that a fire in one of them cannot spread to the other.

4.142 It is equally necessary that, in designing new acetate film stores, large compartments capable of holding hundreds of tons of film should be envisaged only if it is possible to store a duplicate of each film in another compartment at a safe distance. There is no intrinsic objection to large storage compartments for safety film, similar to the stockrooms of large libraries, even in multi-storage buildings; but, unlike books, most of the older films are stored in the form of a single original master copy, in one country only and in one place. Even large libraries have made microfilm of their unique and irreplaceable holdings, which for safety reasons are kept in a different place from that where the books and manuscripts are stored.

4.143 Small archives which cannot afford to maintain more than one film store should at least keep positive and negative copies of the same film in different storage compartments, separated by earth walls if the distance between them is not great enough. In such cases blast vents should not be in the roof but in the wall which faces away from the other storage compartment.

4.144 The best guarantee is, of course, to store a film in different countries. This is what is already being done with the great classic films of international repute already in the archives of several countries. Unfortunately, it is not yet being done with important documentary material. Therefore positives and negatives of films not known to be preserved in other countries should in all cases be stored so apart that in case of an outbreak of fire only one copy of the film is destroyed.

4.2 FILM STORAGE CONDITIONS

Fundamental Principles

4.21 A fundamental principle for all film storage should be the separation of the nitrate stock from the acetate stock, and the storage of colour copies, magnetic film and magnetic tape in the same stores, and under the same conditions, as acetate film.

Cinematograph films and magnetic films are all multilayer materials. When for the different layers of the same film (i.e. the base and the emulsion) different conditions of temperature and humidity are required, the correct standard for storage must always be that of the lowest values. For the permanent storage of film the most important factors are temperature and humidity, ventilation, and the safeguarding of the film and its surroundings against accident. It is these factors which must determine the most suitable form of a film store.

4.22 *Temperature* In determining the correct temperature of a store, regard must be had to both its absolute level and its steadiness. Although the temperature requirements of nitrate and acetate stores differ, it must in each case be steady. Like all other materials, film expands as it gets warm and shrinks as it cools. Continual expansion and shrinkage of the different layers of cinematograph film endangers its preservation life.

4.221 *Nitrate Film* It has been clearly established above that nitrate films are best stored at the low temperatures stated. Research experience in several countries has indicated an optimum of 2°C ±2°C (35°F ±3°F). Although nitrate film disintegrates more slowly at a temperature much lower than 0°C, 32°F (e.g. —18°C, 0°F) the difference is only very small, and is out of all proportion to the great expense, in non-arctic regions, of maintaining a constant temperature of —18°C. Raising the temperature from 0°C to +18°C (32°F to 64°F), on the other hand, results in a quite considerable acceleration of disintegration. Almost all archives store their nitrate films not at the low temperature stated here as ideal, but at temperatures between 15°C (60°F) and 21°C (70°F)*.

One of the most important objections to higher temperatures is that the volume of nitrate gases given off by nitrate film almost doubles with each temperature rise of 5°C (9°F), so that the risk of destruction by disintegration is correspondingly greater.

The most favourable temperature for storing nitrate film is 2°C ±2°C (35°F ±3°F).

4.222 *Acetate Film* The base of acetate film, which does not have the same tendency to disintegrate as nitrate base, could be stored without danger at steady higher temperatures, but, as the life of the emulsion is greatly dependent on temperature and humidity, lower temperatures are advisable.

Magnetic films and magnetic tapes can be stored at the same temperatures as acetate film. For magnetic recordings, however, there is always a danger of the copying effect (see 2.34). Higher temperatures favour this effect, which is sufficient reason for lowering the temperature. Large archives protect themselves against this by transferring their more important magnetic recordings on to optical sound film, which is acetate film and can be stored accordingly.

The maximum storage temperature for acetate film is 12°C ±2°C (54°F ±3°F). When stored together with magnetic films and magnetic tapes, the optimum temperature is 6°C (42°F).

*The National Film Archive in London, while fully accepting these recommendations, has deliberately chosen to keep its nitrate films at a constant temperature of approximately 13°C (55°F) in order to save the cost of air conditioning (which at best could extend the life of its nitrate copies by only a limited period), and to concentrate its restricted resources instead on a systematic programme of copying on to acetate. (*Publisher's note*)

4.223 *Colour Films* Colour films in the form of coloured copies require to be stored differently according to the process used. Kodak gives —18°C (0°F) as the ideal temperature, while Agfa considers that +15°C (59°F) is acceptable. Here it must be stressed again that the best method of preservation is of course in the form of three colour separations which can be stored together with other acetate films (see 1.445).

4.23 *Relative Humidity* The most favourable percentage of relative humidity lies within narrow limits. In 1.231 and 1.42 it was stated that an excessive amount of moisture in the atmosphere favours the decomposition of the emulsion as well as the disintegration of the base, and also encourages the growth of bacteria and fungi. On the other hand, too low a humidity promotes shrinkage of the film and causes it to become brittle. In both cases these effects can lead to the complete destruction of the film.

4.231 The optimum relative humidity depends on the storage temperature, and just as different figures have been quoted for temperature so the figures for the most acceptable relative humidity differ a great deal. Relative humidity figures as widely apart as 50% and 70% have been quoted, but the lower figures only in conjunction with very low temperatures.

4.232 There is no doubt that a relative humidity of more than 60% can be dangerous for film by encouraging swelling of the gelatin and the growth of fungi, and that anything less than 40%, except in conjunction with extremely low temperatures, encourages shrinking. It is also important that the relative humidity should be maintained as steady as possible, and fluctuations of more than 5% should be avoided.

The optimum relative humidity for all types of film lies between 40% and 60%.

4.24 *Ventilation*

4.241 Good ventilation is especially important for the storage of nitrate film (see 1.232); for acetate film normal room ventilation is sufficient.

4.242 Ventilation for nitrate film stores is essential to evacuate the nitrate gases released during the process of disintegration. These gases can be easily detected by their pungent odour, and there is a popular saying that ventilation is only efficient when " it no longer smells of nitrate film ". If one relies on normal ventilation processes, however, it becomes impossible to keep the temperature and the relative humidity constant because the conditions of the outside atmosphere are always being extended to the interior of the store. Air conditioning is complicated and expensive, but unless the atmosphere of the store can be modified by artificial means it is impossible to achieve optimum storage conditions.

4.3 CONTROL OF STORAGE CONDITIONS

Steady low temperatures, a relative humidity varying only within narrow limits, and constant renewal of the air without endangering the levels of temperature and humidity, can only be fully achieved by a system of artificial air conditioning.

Automatic Air Conditioning Plants

4.31 These operate independently of any supervision to give the required temperature, the required relative humidity and the desired amount of ventilation.

4.311 The temperature is controlled by thermostats installed in the storage compartments or vaults, and if any deviation occurs colder or warmer air is at once supplied. Cooling is achieved by means of water or brine. In normal circumstances, cooling down to about 10°C (50°F) can be obtained by the use of running water or well water and, by using brine, temperatures below freezing point can be reached. In large plants this cooling and any heating needed is done centrally. Heating may be by coal, oil, gas or electricity. Air from the outside is led through a filter and purifier into the plant, where it is brought to the required temperature, moistened by sprinklers to give the required relative humidity, and then pumped into the storage compartments. Once the temperature and relative humidity have been adjusted, they are then automatically regulated by thermostats and hydrostats.

4.312 Air conditioning plants can work either by constantly using the air in the store, or by partly using air drawn in from the external atmosphere. The greater the percentage of outside air, the greater the differences in temperature and moisture which have to be regulated by the plant. An intake of 25% of outside air into a nitrate film store means that, with four shifts per hour, the air in the store will have been completely renewed after three hours. Consequently, the relatively small quantities of nitrate gases which are released at very low temperatures and which percolate from the cans into the store itself are constantly evacuated.

In ventilating acetate film stores, the intake of fresh air can be smaller, usually about 8%. In this case the renewal of the air naturally takes longer.

Non-automatic Air Conditioning

4.32 Automatic air conditioning plants guarantee the best storage conditions for all types of film, but unfortunately they are very expensive, so that at present only the largest archives can afford them. Where it is not possible to provide such a plant, other means have to be employed in and endeavour to create the best conditions possible.

4.321 In the Chinese Film Archive in Peking, for example, a refrigerator of the compressor type—without automatic control—is used. In this way it is possible to ensure that the temperature never exceeds a fixed maximum. When the temperature in the store becomes too high, the refrigerators, which stand in the storage building outside the vaults, are set working by an employee of the archive, and cold air is blown in through a pipe in the back wall of the vault while the warm air escapes through an opening in the roof. Such a refrigerator may be able to service one or more vaults, depending on the capacity of the machine, the size of the vaults and the temperature differences. Such a system is much cheaper than an automatic air conditioning plant, but it requires more supervision.

The temperature fluctuations are greater than with automatic plants, and the difference between summer temperatures and winter temperatures can be considerable if, in winter, heating is not substituted for cooling (only central heating would be permissible). Ventilation is provided by the blowing in and escape of air, but a refrigerator of this kind has no influence on the moisture content of the air.

4.322 The moisture of the atmosphere can be regulated by installing dehumidifiers. These, in their most simple form, use potassium cartridges or silica gel, which absorb the moisture from the air and deposit it into closed containers which have to be emptied regularly. There are more complicated installations which work automatically. The Netherlands Film Museum in Amsterdam has had such apparatus in use for several years in order to keep the humidity within reasonable limits in such a humid country. Such a method does not ensure an absolutely steady relative humidity, and it does not guarantee that the upper limits are not exceeded from time to time, but it is an improvement over an entirely uncontrolled situation. It can be installed without any modifications to the storage building and is comparatively cheap.

If the air is too dry, it can be moistened most simply by putting down shallow trays of water.

4.323 Ventilation in a non-automatic system of this kind has to be effected by ventilators which are switched on from time to time as necessary. The air filters through which the fresh air enters must be situated in the wall opposite the ventilator, so that a thorough ventilation of the whole room is ensured. If it is impossible to avoid placing the air filter in the same wall as the ventilator, the ventilator should be supplied with a long suction pipe leading to the opposite wall. Ventilation of acetate film stores can, given a favourable outside climate which is cool and dry, be provided at relatively long intervals. The ventilation of nitrate film stores must be carried out regularly at least once a day, at a time when the air is at its coolest and not too dry, and it needs to be done very thoroughly. This unfortunately makes the maintenance of even approximate storage conditions very difficult.

4.324 A system of non-automatic artificial air conditioning presupposes a constant measurement and control with the aid of accurate thermometers and hygrometers, so that the various installations for cooling, dehumidifying and ventilating can be used as necessary. The cost of maintaining this supervision must be accepted because, particularly in countries with an unfavourable climate, it is of less significance than the danger of storing films without any control of the storage conditions.

4.325 To what extent all these kinds of apparatus are to be permanently installed must depend on the local climate and the nature of the storage buildings. Underground stores and vaults with very thick walls are cool, even on hot summer days, but they are constantly humid, and so dehumidifiers at least have to be used. Lightly constructed buildings above ground are usually dry in summer but need to be cooled.

Building Provisions

When a film archive is putting up a new storage building but cannot immediately afford the cost of air conditioning plant, it should nevertheless make provision in the design of the building for such plant to be installed later. Housing for the plant and the necessary channels should be incorporated, so that when the means are available the air conditioning plant itself can be installed without difficulty and without the necessity of rebuilding. 4.33

Whether the store is to be provided with air conditioning or not, it is desirable to have the walls and roof painted white to reflect heat away from the building, and to spray the roof with water on hot days. Direct heat from the sun should be avoided by the use of natural shadow (e.g. from tall trees) or should be counteracted by double roofing. Where double roofing is used, the roof should slope slightly on the side towards the sun in order to obtain a constant ventilation by wam air ascending between the roofs. Further advice on this will be found in section 5.2.

Storage Tests

For several months the research department of the Soviet Film Archive, Gosfilmofond in Moscow, has been carrying out some interesting tests on the storage of both black-and-white and colour films. For the purpose of one of these, special cold rooms were constructed where films could be stored at temperatures from —5°C to +5°C (23°F —41°F) in airtight containers and under normal atmospheric pressure. Parallel with these, other films are being stored in air-tight containers at normal temperatures. These tests will take a considerable time to complete, but it is to be expected that they will result in an increase of our theoretical knowledge which will have practical consequences for future film preservation. The results will be published in due course. 4.34

FIRE PREVENTION

For acetate film the normal precautions against fire which are taken in libraries, office buildings, etc., are sufficient, but in nitrate film storage fire prevention plays a decisive role. 4.4

Forms of Fire Protection

There are three possible forms of protection against fire: 4.41

(i) The prevention of outbreak of fire by appropriate installations in the storage buildings and by the maintenance of favourable storage conditions, particularly storage at low temperatures.
(ii) The prevention of fire spreading, isolating it within the smallest possible units, by appropriate division of the storage space and by the use of pressure vents.
(iii) The keeping of all fire extinguishing apparatus in constant readiness, giving appropriate instruction to all workers in the archive, and having an instant and reliable alarm system to warn the local fire brigade.

Preventive Measures

The most important of these are the preventive measures. When nitrate film has once started burning it cannot be extinguished by any known means. Everything depends on preventing the start of a fire, and failing this, restricting it to the smallest possible area. Apart from the design of the building and atmospheric conditions of storage, the most important thing is the instruction of all workers in the archive, the training of staff in initial fire fighting measures, the regular exclusion from the storage rooms of all those who are not employed there, a ban against introducing burning materials of any kind within a zone of 50 metres (165 ft.) from the storage buildings, and flashproof connections for all electrical fittings*. 4.42

Isolation of the Fire

4.43 If, in spite of all precautions, a fire should break out in a nitrate film store, the first necessity is to try to isolate it by providing an escape for the gases of combustion, which can be given off with an explosive force. For this reason it is essential that every enclosure in which nitrate film is stored should have an outlet to the outer air which will open automatically as the temperature rises. Panes of glass are not sufficient as pressure vents, since to splinter a glass pane of normal thickness requires a considerably larger force than should be necessary to release the mechanism of a pressure vent. The walls and doors of nitrate film vaults must, of course, be fireproof. It has already been observed that burning nitrate film cannot be extinguished by the usual means, because it produces its own oxygen during burning. For this reason it can continue to burn under carbon dioxide gas and even under water.

Extinguishing Methods

4.44 In general, methods to counteract fire are restricted to the installation of water sprinklers, the water having no value as an extinguisher, but only to cool the surrounding area so as to limit if possible the spread of the fire. It is also possible to use carbon dioxide gas sprinklers, but as this is a rapidly acting dangerous gas, any part of the building which is likely to be filled with it in case of an emergency must be evacuated by all personnel within a few seconds. The area can only be re-entered by all personnel within a few seconds. The area can only be re-entered without breathing apparatus after thorough ventilation. Furthermore, the carbon dioxide gas does not extinguish the burning film; it only excludes atmospheric oxygen and prevents the formation of flame.

4.441 To protect the surroundings in the event of a conflagration, hand fire extinguishers or other appliances, particularly fireproof covers, should be ready for use in the immediate vicinity of the origin of the fire. They should also be installed in corridors, near the doors of the vaults, on staircases, at exits and in all the work rooms. The hand fire extinguishers are generally filled with carbon dioxide or a fire-extinguishing foam. The foam will spoil any film with which it comes into contact, but it has the over-riding advantage that it may prevent the fire spreading.

Instruction of Personnel

4.45 All the members of the staff of a film archive should be given regular instruction; in some countries it is officially laid down that this should be done as frequently as once a month. It is most important that this

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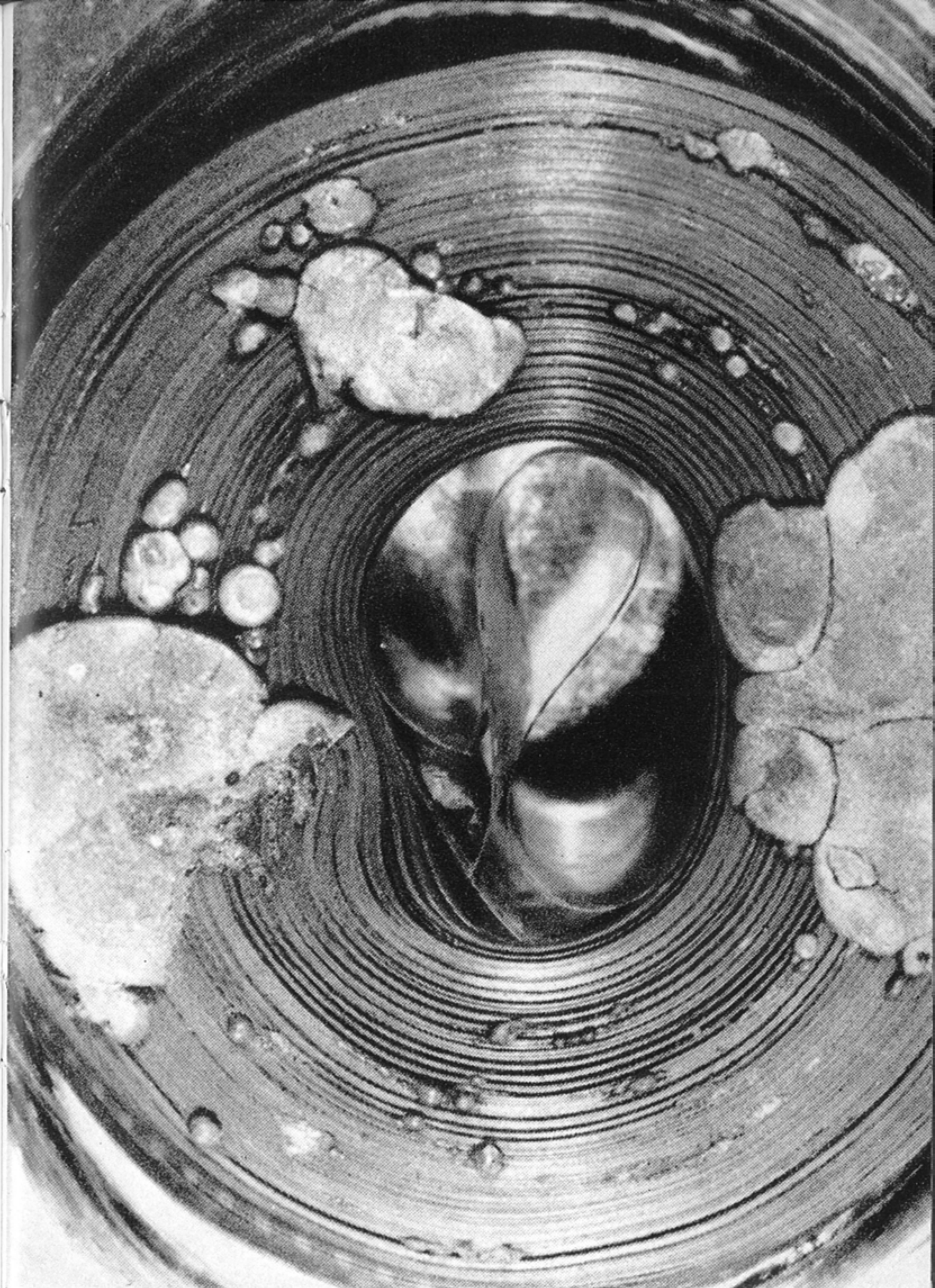
*The film stability test (see 6.14) also contributes to fire prevention by enabling deteriorating nitrate film to be systematically detected, copied on to new acetate film, and then destroyed. (*Publisher's note*) instruction should be given by experts, and in particular the use of fire extinguishing appliances should be practised. An outbreak of fire in a nitrate film store which is not so built as to confine the fire to one small unit, and where there is no automatically operated extinguishing installation, develops at such speed that only during the first few minutes is there any possibility of limiting the fire. This means that the first effort at quelling the fire must be taken by the archive staff, since too much time must elapse before the arrival of the professional fire brigade to leave the fire unattended.

Alarm to Fire Brigade

Despite this, however, every nitrate film store should have a direct alarm connection to the local fire brigade, who should always be called in order to prevent the spread of the fire to its surroundings. 4.46

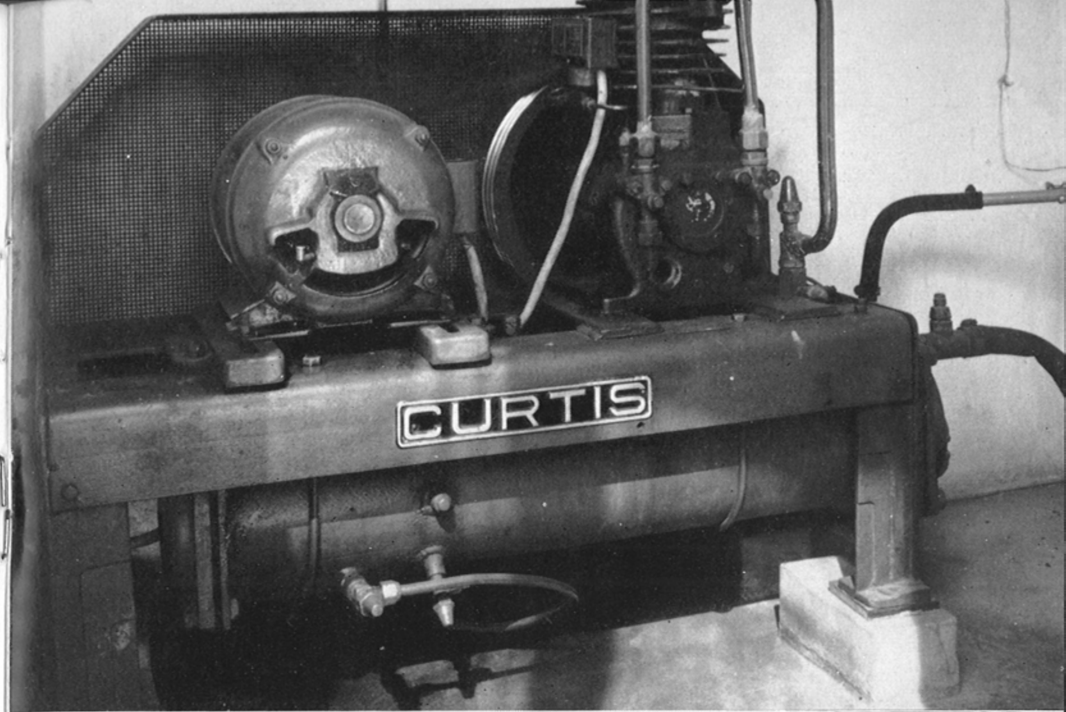
Burglar Alarm

In a nitrate film store it is also necessary to provide precautions against burglary. It is absolutely necessary to ensure that at no time can any unauthorised person enter the film store. What measures are taken against burglary must depend upon local conditions; it is always better, however, to do too much in this respect than too little. 4.47



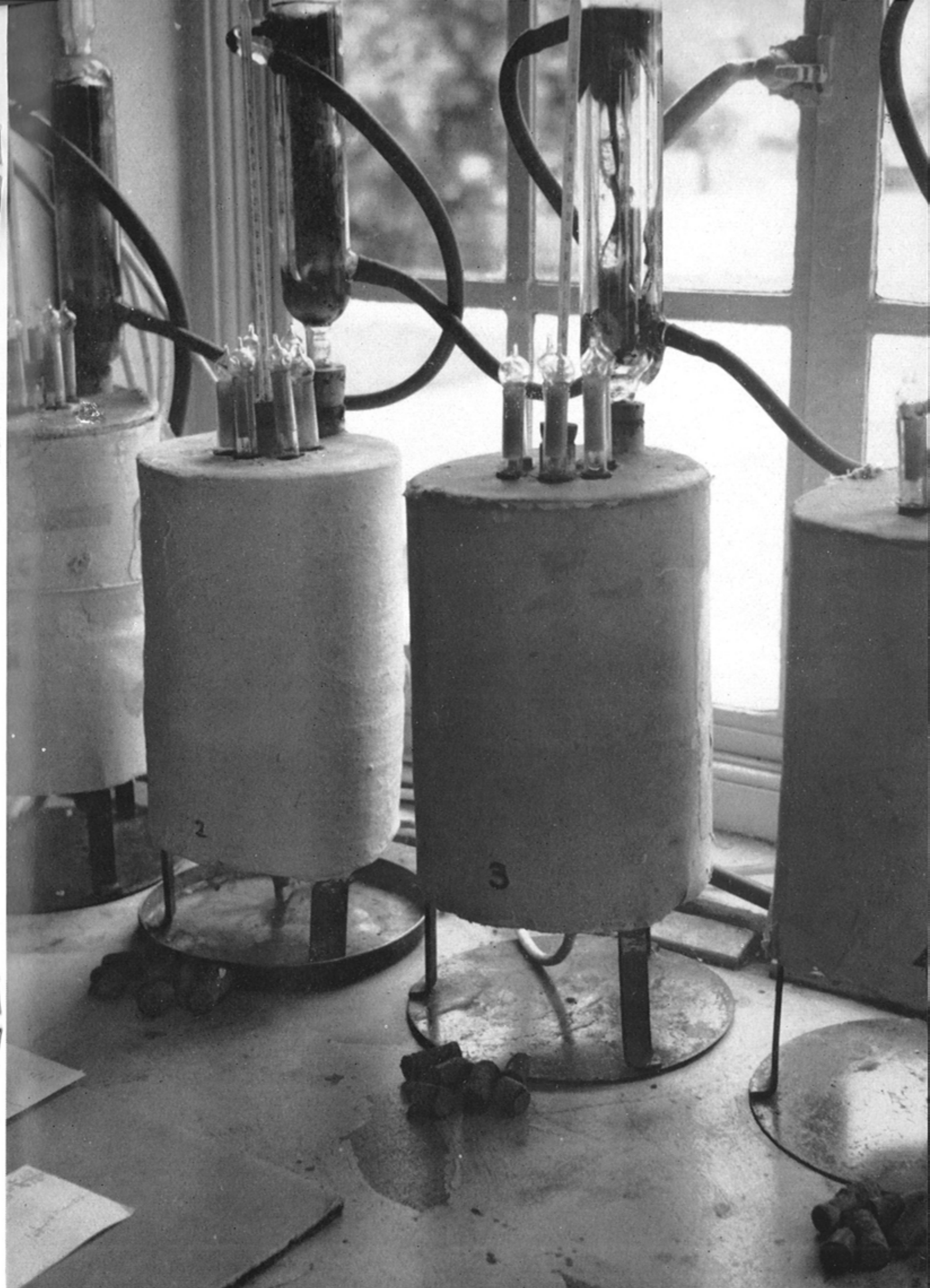
1. Nitrate film in final stage of decomposition (*Museum of Modern Art Film Library, New York*)

2. (*Above*) Pressure vents at nitrate film store (*National Film Archive, London*)
(*Below*) Acetate film store (*Yugoslovenska Kinoteka, Belgrade*)



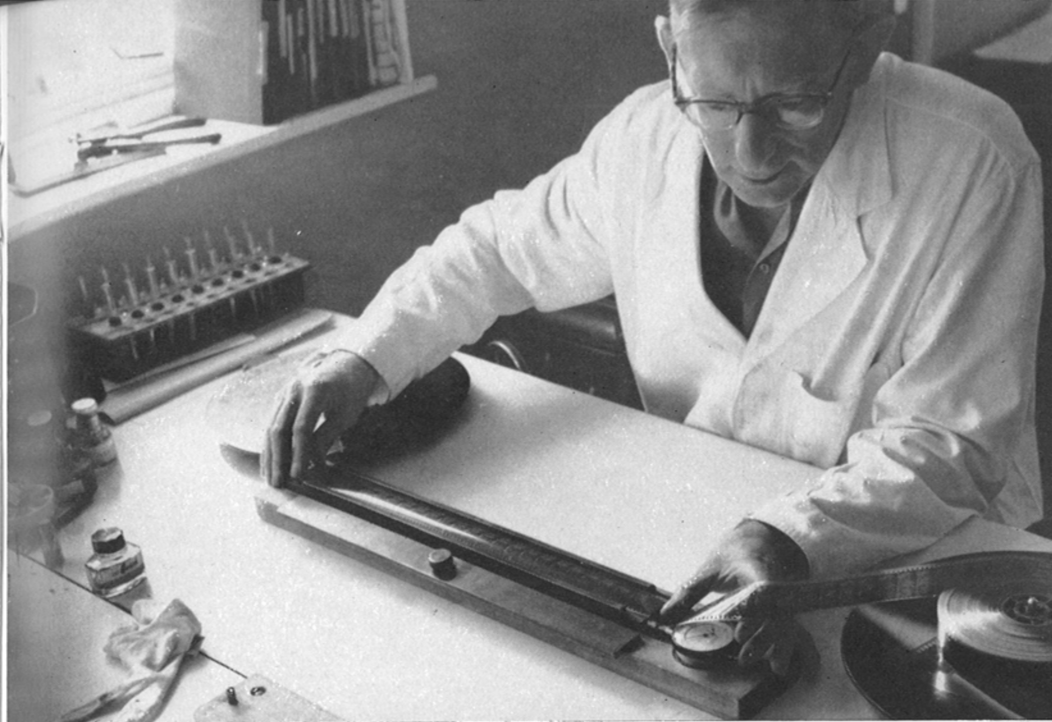
3. (*Above*) Air-conditioning installation
(*Below*) Vault interior, with air-conditioning outlet (*Cinemateca Nacional, Lisbon*)

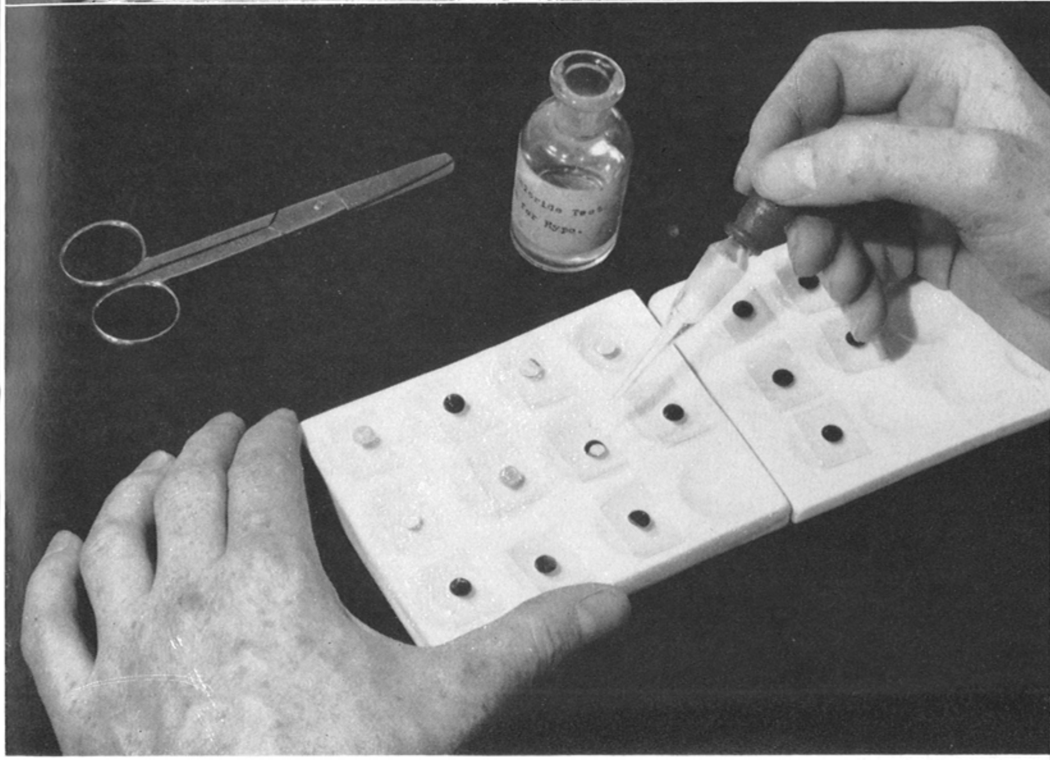
4. Film Stability test for nitrate film: taking sample punching



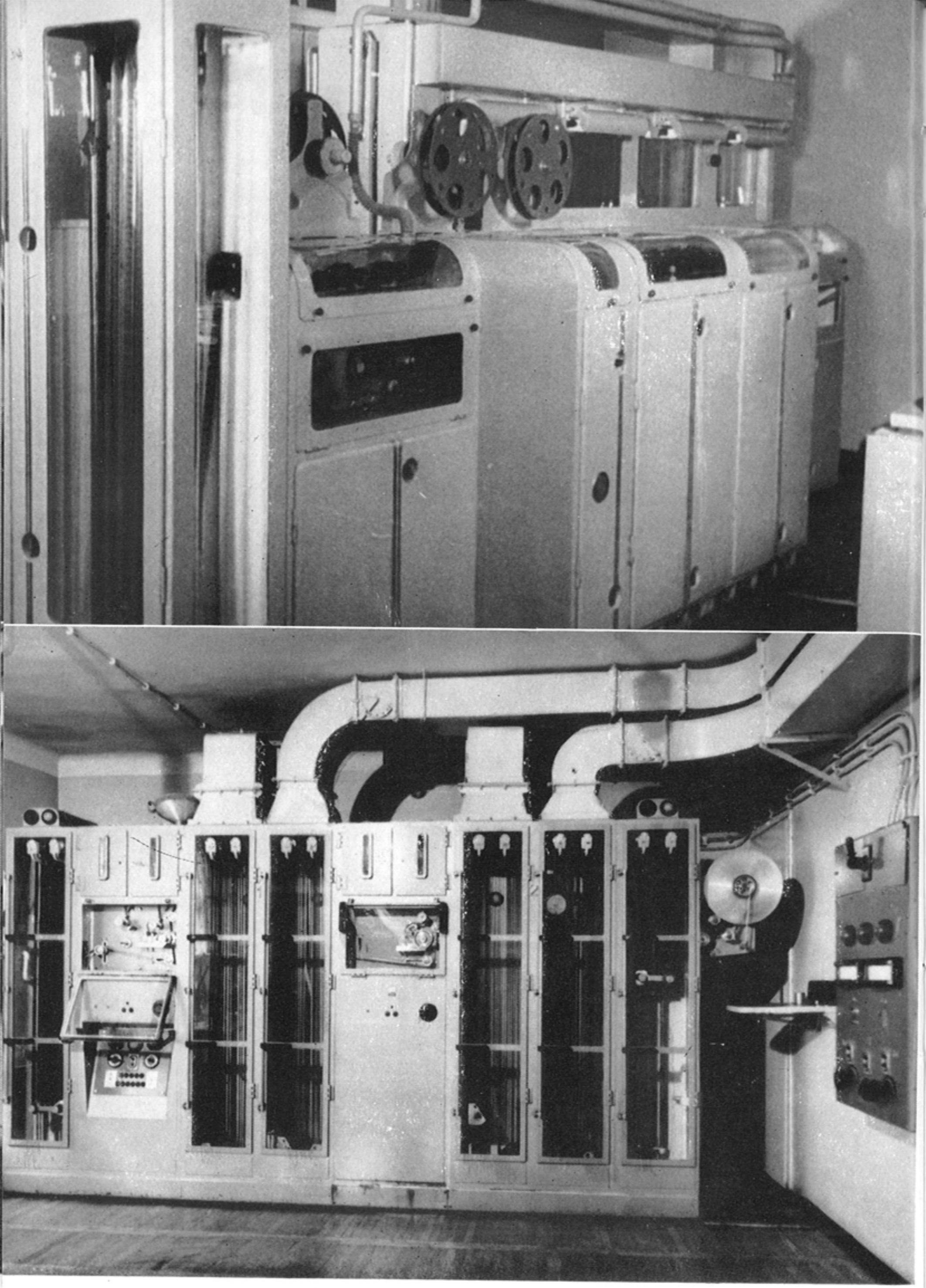
5. Electric ovens for film stability test

6. Film examination—(*Above*) Centralne Archiwum Filmowe, Warsaw
(*Below*) National Film Archive, London





7. (*Above*) Measuring shrinkage (*Below*) Residual hypo test



8. Combined restoration machines— (*Above*) Gosfilmofond, Moscow
(*Below*) Centralne Archiwum Filmowe Warsaw

5. STORAGE BUILDINGS

5.1 POSITION

5.11 Buildings for the permanent storage of all types of film should be sited away from big cities or industrial areas for the following reasons:

(1) Wherever coal is burned in large quantities the air contains sulphurated hydrogen, sulphur dioxide and possibly other acid compounds, which will eventually damage the film base.

(2) In cities or regions which have a great deal of traffic, there is considerable danger of pollution by dust. Unless the ventilation plant of the storage building is equipped with very expensive dust filters, scratches can be made on the film by particles of dust during inspection or exhibition.

(3) For nitrate film, in particular, siting in densely populated areas is prohibited by the abnormal fire risk.

5.12 Ideal conditions for the building of film stores are to be found away from large cities and industrial centres, in woods, on dry ground with a low subterranean water level, and not in the vicinity of large lakes or marshes. In such situations there is no danger of the films suffering damage from the high proportion of acid in the air. The pollution from dust is low, and it can be diminished further by cultivation of the surroundings, for example by laying down lawns. The woods give natural shade to the buildings, and there are no dwellings in the immediate neighbourhood to be endangered. A good choice of site is particularly important when it is not immediately possible to establish ideal storage conditions.

5.13 For the building of nitrate film stores most countries have legal requirements laying down the minimum distance from inhabited buildings. As a result of experience gained from the big film fires of the last few years, it has been realised that these legally prescribed distances are too small. The regulations were made several decades ago, at a time when nitrate film was not yet old enough for the increasing danger of ageing film to be properly appreciated. Experience has shown that during some big film fires burning reels of film have been hurled for distances of more than 200 yards, so that the whole region within this radius must be regarded as dangerous in the event of an accident.

Whenever possible, new nitrate film stores should be placed at least 250 yards away from the nearest inhabited dwelling.

DESIGN OF STORAGE BUILDINGS 5.2

5.21 At present there are as many types of film store as there are archives, partly because in the past only a few archives possessed the fundamental knowledge of conditions for the permanent storage of film, partly because climatic conditions vary very considerably from one country to another, and not least because of financial limitations.

In building a film store, it is possible to achieve the goal of storing under optimum conditions in a number of different ways. There are three different types of store in use, as follows:

(i) At ground level, equipped with air conditioning plant (Moscow, Gosfilmofond)

(ii) Underground, with air conditioning plant (Berlin, State Film Archive of the German Democratic Republic)

(iii) At ground level, built with thermal insulation (London, National Film Archive).

Ground-level Store with Automatic Air Conditioning Plant

5.211 Gosfilmofond has developed three types of store: one for nitrate film, one for acetate film, and one for exceptionally precious films. All three types are built at ground level on a foundation of stone and concrete. The outer walls are 78 cm (31 in.) thick, made of hollow brick, and the interior walls are 38 cm (15 in.) thick. The ceiling consists of flat slabs of reinforced concrete with an insulation of foam concrete, and the roof is covered with three layers of rubberoid sealed with asphalt. All the storage buildings have automatic air conditioning plants.

The nitrate film stores hold 70 tons of film, distributed amongst 28 vaults containing 1000 reels each (2·5 tons). Each group of three vaults has a common corridor with a door to the outside. All doors are fireproof and all vaults are fitted with pressure vents. The climatic conditions maintained in the store are:

Temperature, 12°C ±2°C (54°F ±3°F); relative humidity, 55—65%; 30% fresh air. The films are stored on steel racks with hardwood shelves.

The acetate film stores have a capacity of 100 tons in two storage compartments of 20,000 reels each (50 tons).

The entrance to the storage compartments has an airlock. The climatic conditions maintained are: temperature, 12°C ±2°C (54°F ±3°F); relative humidity 55—65%. The films are stored on steel racks.

The store for particularly precious films has a capacity of 51 tons (20,400 reels). Each reel is stored in its own fireproof compartment, closed with a flap, and each compartment has a pressure vent opening into a channel which leads to the outside air. The climatic conditions are: temperature, 0°C (32°F); relative humidity 55—65%; 30% fresh air.

Underground Store with Automatic Air Conditioning Plant

5.212 Up to the present time the State Film Archive of the German Democratic Republic in Berlin has had ground-level stores with a controlled temperature of 10°C ±2°C (50°F ±3°F). The new storage buildings, which are now being constructed, have, in addition to a non-conditioned store for distribution films of 12·5 tons capacity, two types of underground stores for nitrate film and acetate film. The outer and inner walls are of brickwork with heat insulation. The ceiling and roof consist of reinforced concrete, again with a layer of insulation.

The nitrate film stores have a capacity of 100 tons each, distributed amongst 40 vaults each holding 2·5 tons (1000 reels). All vaults have fireproof doors to a central corridor and pressure-operated vents to the outside air. The climatic conditions maintained are: temperature, 2°C ±2°C (34°F ±3F); relative humidity, 50—60%; 25% fresh air. The films are stored in fireproof cabinets holding 10 reels each, which can be ventilated.

The acetate film store has a capacity of 300 tons, distributed between 6 fireproof compartments each of 50 tons capacity (20,000 reels). The staircase, lift and air conditioning plant are in the centre of the store, and at each end are emergency exits (as in the nitrate store). The films are stored on open steel racks. The climatic conditions are: temperature, 6°C ±2°C (42°F ±3°F); relative humidity, 50—60%; 8% fresh air.

Ground-level Store with Thermal Insulation

5.213 The British National Film Archive in London has developed and built for its nitrate film a type of store which can be recommended to all those who cannot immediately instal an air conditioning plant. Each storage building has a capacity of 28 tons distributed between 28 vaults of 1 ton (500 reels) each. The outer walls are 40 cm (16 ins) thick, and have the following composition:

brickwork	11.25 cm	(4½ in.)
hollow space	5 cm	(2 in.)
brickwork	11.25 cm	(4½ in.)
glass wool	2.5 cm	(1 in.)
thermal insulating block	10 cm	(4 in.)

The roof is made of reinforced concrete, 15 cm (6 in.) thick. In this brick building are housed the 28 vaults, in two rows of 14 vaults each, back to back, but surrounded by an air passage. Between the vault ceiling and the roof of the outer brick building there is also an air space, with an outlet for warm air. The corridors have automatic electric heating, which comes into operation in the winter when the temperature falls below 13°C (55°F). All the vaults have pressure-operated vents in the roof. The British National Film Archive states that this form of building makes it possible to keep the internal temperature of the vaults at about 13°C (55°F), except in the case of extreme outside temperatures.

The Archive is now planning the building of a store for acetate film with large storage compartments and an automatic air conditioning plant.

Multi-storey Buildings for Nitrate not Recommended

5.22 There are still other interesting solutions, for example in the store of the Cineteca Nazionale in Rome, where very small fireproof compartments each contain 12 reels of film; or in the Norsk Filminstitutt in Oslo, which has its store in a space blasted in the rocks of a fjord; and many others. Warning should be given, however, against the practice of storing nitrate film in vaults with a capacity of 1000 reels or more placed one above another in multi-storey buildings.

Insulation and Air Conditioning

5.23 The harmful effect upon permanently stored film of dampness and high temperature makes it impossible to stress too greatly that insulation from ground moisture, prevention of the penetration of summer warmth, and protection against excessive atmospheric moisture are the most important elements to consider in the construction of a film store. If, for economic reasons, new storage buildings (whether for nitrate or acetate film) cannot be provided with an air conditioning plant immediately, it is urgently recommended that its future installation should be envisaged by making provision in the building for the necessary openings, channels, etc., so that the plant can eventually be incorporated without any rebuilding. Such channels and openings must be rendered fireproof until the automatic fireproof flaps of the air conditioning installation are built in.

STORAGE BUILDINGS FOR NITRATE FILM 5.3

Total Capacity

The capacity of a nitrate film store will depend upon the safety measures 5.31 which have been taken to prevent a fire starting within the store or spreading to it. The most important safety measure is to lower the temperature to such an extent that spontaneous ignition is, to the best of our knowledge, made impossible. For various reasons it is accepted that the optimum storage temperature lies near to 0°C (32°F). With the film cooled to this extent, and given ample fire precautions, relatively large stores with a capacity of 100 tons or more can be built. But it is necessary to stress that in this case the possibility of a conflagration, with total destruction, and danger to the surroundings, remains. When nitrate film is stored in temperate or warm zones without air conditioning, it is essential that the vaults are kept as small as economically possible.

Capacity of the Vaults

The capacity of the vaults (i.e. the fireproof units in which generally 5.32 500 or 1000 cans of nitrate film are stored on racks) is of great importance in limiting the scale of a fire. The regulations in England do not allow more than 500 cans each holding 1000 feet of nitrate film to be stored in any one vault; in several other countries the storage of 1000 cans is permitted. For 1000 cans each holding 1000 feet to be stored on open racks 12 in. deep, a wall space of 20 sq. yds. is necessary. If they are stacked along the two long walls to a height of 8 ft., this requires a vault some 7½ ft. long, 8½ ft. high and 6½ ft. wide. No more than 1000 cans should be stored in one vault. If the vault is made longer, there must be an emergency exit in the rear, which makes air conditioning more difficult.

Racks, Partitions and Compartments

There are several ways of storing the cans. The most simple method is 5.321 to put them on open shelves (made of steel, wood, concrete, etc.). In the event of fire, the whole contents of the vault will be lost.

A second method is to store them in compartments open at the front, each holding one or two cans, and made of fireproof materials to a thickness of at least 1 can. It is considered in the USA that such a construction, aided by an automatic sprinkler installation, will ensure that any outbreak of fire is confined to one compartment.

Thirdly, one or more cans can be stored in enclosed pigeon-holes or compartments, the compartment being fire resistant and capable of

ventilation. It also needs to have a pressure flap opening to the outside, or the door must act as a pressure-operated opening. If automatic sprinklers are employed then it is possible to limit the fire to a very small unit.

Air Conditioning and Ventilation

5.33 Under 4.221 and 4.31, reference has been made to the artificial air conditioning of nitrate film stores, and to the desired optima. The optimum values are: temperature, 2°C ±2°C (35°F ±3°F); relative humidity, 40—60%; supply of fresh air, 25%. This low temperature is necessary not only for reasons of safety, but primarily to check the rate of disintegration. If the quantity of nitrate gas given off from a 1000-ft. reel of old nitrate film at 0°C (32°F) is reckoned as 1, then this quantity at 5°C (41°F) will be 2, at 10°C (50°F) it will be 4, at 15°C (59°F) it will be 8, and at 20°C (68°F) it will be 16. In other words, at 20°C (68°F) not less than 16 times as much nitrogen peroxide is formed as at 0°C (32°F). This becomes all the more important when it is remembered that the gases develop within closed cans which allow comparatively little ventilation. Low temperatures are extremely important for the preservation of nitrate film. When, for reasons of economy, it is not possible to install an air conditioning plant, an attempt should be made to approximate to the optimum conditions as nearly as possible by other means (see 4.32 and 4.33).

Fire Prevention

5.34 The structural and climatic conditions for preventing the outbreak and spread of a conflagration have already been dealt with in preceding sections, so that it remains only to deal with specific fire prevention measures.

Pressure Vents

5.341 The most important of these is the pressure-operated blast vent, which releases the pressure of the very rapidly developing gases of combustion into the open air, and thereby prevents an explosion. 6 pounds of stored film need an opening of at least 1 sq. in., which means that in a vault with 1000 reels (2·5 tons) the opening should be 6 sq. ft. The flap which normally closes the opening should move very easily (particular care must be taken against rusting) and it should open automatically under a force of 13 pounds. The hinges should be placed so that the flap opens downward by its own weight, and not so that it opens sideways, or even has to be lifted up. The opening can be placed in the roof, or in the top of the wall, and it should lead to the open air by means of a channel which has a cross-sectional area equal to that of the opening itself. Fixed windows or panes of glass are not sufficient, since the breaking of a glass pane requires a far greater force than that which should be able to open the flap.*

Sprinkler Installations

5.342 As has already been stated, the fire of burning nitrate film cannot be extinguished. Therefore the only purpose of installing sprinklers is to

*It will be observed that the warning here is (very properly) against *fixed* windows or panes of glass. It may be helpful to add, however, that the National Film Archive in London, which has installed pressure vents exactly as described here, controls the ventilation (and therefore the heat transference) through the vents by means of very thin glass plates loosely resting on pegs across the lower openings of the vents, and partially blocking them. These glass plates will move with a very slight pressure. (*Publisher's note*) confine the fire to its place of origin. Usually water is used, not for the purpose of extinguishing, but for the purpose of cooling. For a vault holding 1000 cans, 8 sprinkler nozzles are sufficient for moistening the walls. The installation comes into operation when a predetermined room temperature has been reached (usually between 60° and 90°C, 140° and 194°F).

Sprinkler installations cannot protect films on open racks, but they can protect films in pigeon holes or compartments of fireproof material (e.g. plaster mixed with asbestos). When the sprinklers have been in action, all the cans in the vaults concerned must be wiped dry, and inspected to discover whether any water has penetrated into the inside of them. Besides water sprinklers, carbon dioxide installations can be used. Carbon dioxide has no value for extinguishing burning film, but it prevents the formation of flame. It has the advantage that it does not damage the film with which it comes into contact, but on the other hand it has the very great disadvantage that it is a deadly gas, which can be fatal within a few minutes. Stores in which carbon dioxide installations are used must be evacuated, in case of fire, within a few seconds. In view of this, water sprinklers are preferable, although they are very imperfect for their purpose.

Hand Fire Extinguishers & Fireproof Covers

All that is necessary has been said about these under 4.441. 5.343

Doors and Airlocks

Vault doors and all other doors in nitrate film stores should be made of 5.35 fireproof material. Usually they consist of steel outer layers, filled with asbestos cement (the two steel layers should not touch each other) or of steel with an underlayer of asbestos and hardwood. All doors must open outwards. The vaults should not have a direct exit to the open air. Corridors can serve as airlocks to provide insulation from heat and air pollution; they may be either central, or may surround the vaults, and may be in front of one vault only (although this is likely to be the case only in an acetate store) or they may connect a whole row of vaults.

Emergency Exits

All larger stores with an internal entrance should have emergency 5.36 exits, which can open directly to the outside in case of necessity. Emergency exits should never be locked on the inside, and it should always be possible to open them by a slight pressure on the latch. There is no great need for them to open from outside.

STORAGE BUILDINGS FOR ACETATE FILM

Whereas the design of nitrate stores is greatly influenced by fire preven- 5.4 tion requirements, this is not the case with acetate stores. Acetate film presents no greater fire hazard than ordinary paper, so the fire precautions need be no more elaborate than those which are observed in large libraries.

Storage Units

In the construction of storage buildings for acetate film, there is no 5.41 need for the storage units to be as small as possible, and quite large rooms can be used. This should always be taken into account when new buildings are being considered, because it obviously makes for a much more economical form of construction than when small vaults

have to be provided. It is nevertheless wise to keep within certain limits in this respect in order to avoid very large losses in the event of a fire occurring for reasons having no connection with the storing of film. Above all, as was made clear in 4.141, negative and positive copies of the same film should be stored separately.

Partitioning Against Fire

5.42 As a safeguard against accidental outbreaks of fire, very large stores (those with a capacity of 100 tons or more) should be subdivided into smaller sections separated by fire-resisting partitions. There is no standard size of such sections. The largest up to the present have had a capacity of 50 tons (20,000 cans). Given adequate safety measures, there is no objection to storing acetate film in buildings of more than one storey.

Shelving

5.43 Acetate film can be stored on open racks, for which, in general, steel is recommended. For magnetic film, wooden racks *must* be provided.

Air Conditioning

5.44 Air conditioning is as important for acetate films as for nitrate, despite the absence of any danger of disintegration. Because acetate film has potentially a much longer life, it has to be treated more carefully in order to preserve the properties which give it greater durability. Moreover, acetate film has the same emulsion as nitrate film and therefore the control of moisture and temperature, which is necessary for the emulsion of nitrate film, is just as necessary for acetate. In general it can be said that for the storage of acetate film there is no need for such low temperatures as for nitrate film, but a cool store is better than a warm one. Temperatures of 12°—15°C (54°—60°F), and a relative humidity of 50% to 60% maximum are recommended. It has to be remembered that, although we have had little experience of the signs of ageing of acetate film, it is nevertheless known that it gives off acetic acid in small quantities, and that the plasticiser also evaporates; it would therefore appear to be advisable to use low temperatures here also in order to inhibit these chemical reactions. Since an acetate film store can also be used for the storage of magnetic film and tape, for which the most favourable temperature is 6°C, 42°F (see 2.424), it is recommended that this be maintained as a constant temperature for the whole store, with a maximum relative humidity of 60%.

Ventilation

5.45 Since no injurious gases have to be disposed of, air conditioning with circulating air, and a low percentage of fresh air (about 8%), is sufficient.

COMBINED STORAGE OF ACETATE & NITRATE

5.5 If a film archive is obliged temporarily to store both acetate and nitrate film in one building, then of course the rules and conditions for nitrate film must be observed, even though only some of the vaults contain nitrate film.

5.6 OTHER REQUIREMENTS

Films not to Leave the Store

5.61 There is more to film preservation than the provision of suitable storage buildings. The film has to be rewound, examined, renovated and eventually copied. If possible, it should not leave the repository for all this work. Naturally the allocation of space must depend upon the size of the archive, its financial position, and its technical facilities. Film work rooms must not be in the same building as nitrate film stores, since this would increase the danger of fire.

Provisions for Technical Work The following space and equipment are needed for technical work: 5.62

Film inspection room with rewind tables (driven by hand or motor), shrinkage measurers, magnifying glass for perforations, film joiners;

Chemical laboratory, with all necessary equipment for identifying nitrate and acetate film, for operating the film stability test, and for the detection and removal of any residual chemicals left from development;

Restoration room, with bath for soaking sticky films, film drying equipment, device for repairing perforations, humidifying cabinet, film washing and cleaning machines, apparatus for polishing and for coating treatments; or, instead of these individual machines, a combined restoration installation;

Cutting room, with cutting table for viewing and identifying films, and for making editorial restorations;

Printing laboratory, with printing machines and anti-scratch device, and developing machines for positive and negative, black-and-white and colour;

Viewing room, with projectors to run at 16 and 24 frames per second.

This list is to enable a full programme of activity to be carried out. Amongst all the film archives, only Gosfilmofond in Moscow has such complete equipment; all other archives have some part of it in greater or lesser measure.

Card Indexes Finally, each film store requires the following: 5.63

A technical card index, giving all necessary data and the results of all tests carried out on each film, and

A storage card index, indicating where any given film may be found at any time.

6. FILM STORAGE PROCEDURES

PREPARATIONS FOR STORAGE

6.1 Every film, when it first arrives in the archive, must be inspected carefully before it is put into the store, in order to ascertain its condition.

First Inspection

6.11 The first inspection is made on the winding table. The title on the can or on the delivery note is compared with the title on the leader. Then the film is slowly rewound and carefully inspected, in order to determine whether any signs of disintegration are already visible, whether it has suffered any mechanical damage (scratches or tearing of the perforations), whether the joins are intact, and if any chemicals are separating out. At the same time the film is measured.

6.111 In order to permit a thorough inspection, the winding through of the film should not be too fast (no faster than 2,000 ft. an hour) to allow for adequate inspection and small repairs, for example the securing of joins. This first inspection at the winding table is necessary to ascertain, in general terms, any damage to the film and particularly to the perforations, so as to determine what subsequent treatment of the film may be necessary.

6.112 At the same time, the shrinkage is measured by means of a shrinkage meter or measuring rod.

Cleaning the Film

6.12 If the film has not come straight from a laboratory, the next step is to have it chemically cleaned. If the condition of the perforations and the degree of shrinkage permit, the film can be cleaned mechanically.

6.121 For cleaning purposes any of the following may be used:

Chemically pure carbon-tetrachloride (which has the disadvantage that, when used frequently, it tends to dry out the film);

A mixture of carbon-tetrachloride and toluene 1 : 5;

Trichloroethylene;

Freon.

With the exception of freon, which is very expensive, the fumes given off by all these liquids are very injurious to health. They should only be employed under conditions of adequate ventilation.

6.122 There are two types of cleaning machine. In the first, the film is moved through the cleaning bath over rollers. Thereafter it passes between foam rubber squeegees, which remove the dirt and liquid, and finally it is mechanically cleaned with brushes, chamois leather or velvet.

6.123 The second and newer type is the ultrasonic cleaning machine. Here the film, in passing through the cleaning bath, is subjected to vibration, which loosens the dirt and allows it to be washed away. Immediately after the film leaves the bath, any liquid still adhering to it is blown off so that the dry film can be rewound at once. This ultrasonic machine has the advantage that the image-bearing part of the film is not touched mechanically in any way during the cleaning process, and consequently cannot be scratched by particles of dust, etc.

6.124 If an archive has no cleaning machine, the film must be cleaned by hand, either at the winding table or, when it is very dirty, on a pad. The cleaning liquids are the same as those used with a mechanical cleaner (see 6.121). If a very soft cloth (e.g. velvet) is used for cleaning, the film is given an electrostatic charge by friction; it then attracts dust and fluff with results quite contrary to those desired. Therefore an anti-static cloth, which cannot charge the film, must be used. Very dirty and oily films should first be passed through a cloth soaked in the cleaning liquid, then wiped dry at the winding table with an anti-static cloth.

Distinguishing Nitrate and Acetate Base

6.13 It is also necessary to ascertain whether the film under examination is on nitrate or acetate base. This distinction, which has to be made in order to store the two types separately, must be determined in a way which leaves no room for any doubt as to the result.

Edge Marks

6.131 The most simple way to identify is by edge marks. Except for original films made in the earliest years of the production of raw stock, all films are marked on the edge with the name of the stock manufacturer, and with the indication " nitrate ", " safety " or ' S '. Identification by these marks is irrefutable if one is dealing with original negatives or copies, or with duplicating positives printed from such negatives. But the more often a film is duplicated or copied, the more difficult it becomes to identify the original edge marks because the edge marks of all the intermediate versions find their way cumulatively on to the final one. It is therefore advisable to rely upon edge marks only where no doubt can arise, and in all other cases to resort to one of the following tests.

Burning Test

6.132 A small piece of film (about half a frame of 35mm film) is cut off from the film to be tested and held in a flame. If it burns instantly with a fierce flame, then it is nitrate film; but if it only smoulders slowly, it is acetate film. With the very small pieces used for this test, however, mistakes cannot be excluded, since the burning time often varies with the make of film. It is therefore recommended that the test be carried out by an experienced assistant. The disadvantages of this test are that, first, the film has to be cut, involving the loss of a frame and often the making of a new join; second, the test cannot be carried out in the examination room, or in any other room where films are present, but only in a special place where the burning of film is permissible. It is vital to observe such safety measures.

Floating Test

6.133 This test depends on the fact that the specific gravities of nitrate film and acetate film are different. When a piece of nitrate film is put into a container filled with trichloroethylene, it will sink. If the same is done with a piece of acetate film, it will float, because the specific gravity of trichloroethylene lies between that of nitrate film and that of acetate film. For this test, only very small pieces of film are required, punchings with a diameter of $\frac{1}{4}$ in., so that no significant damage to the film need be caused. It is essential to take this piece from the picture part of the film, and not from the leaders at the beginnings or ends of reels, since these are often joined on, and can be on a different base.

Trichloroethylene is toxic, and should only be used with great care. If a large number of films are to be tested, this work should be done in a separate room with adequate ventilation. If it is done only occasionally, it can be carried out in the examination room. A small quantity of trichloroethylene can be kept on the work table in a bottle with a ground glass stopper.

Chloroform Test

6.134 If the base side of acetate film, at a point where it has been scraped, is lightly touched with liquid chloroform, it will show immediate signs of dissolving. The celluloid side of nitrate film, which has been similarly scraped, will not be affected by chloroform. The scraping is necessary to remove the thin layer of lacquer which might give a misleading result.

Chloroform is toxic and can be used only in rooms with adequate ventilation.

Methanol Test

6.135 The procedure is the same as with the chloroform test, but here it is the nitrate film which dissolves when it comes into contact with methanol, while the acetate film is not affected. The result is immediately perceptible.

Methanol is poisonous, but the test can be carried out in the examination room. The liquid can be kept in small tightly-stoppered drop bottles.

Fluorescence Test

6.136 A very simple and sure way of determining the type of film being handled is provided by the fluorescence test. This method can be used only for Kodak material. Kodak has applied to its acetate films a very small amount of fluorescent chemical, which glows under an ultra violet lamp. If a mixed reel of nitrate and acetate film is viewed on edge under a suitable ultra violet lamp in a partially darkened room, a vivid fluorescence is visible in the acetate parts of the reel, but the nitrate parts remain black. As this test is only applicable to Kodak film, the result is only reliable when the film fluoresces, or when there is absolutely no doubt that the films being tested are of Kodak manufacture.

6.137 In conclusion, it can be said that both the chemical tests and the floating test are easy to apply and give reliable results. It is desirable to be equipped for two different methods of testing, since it is always possible that with certain films the first test may yield an indeterminate result.

The Film Stability Test

6.14 When it has been ascertained that the film under inspection is nitrate film, it is strongly recommended that it be subjected to a film stability test*. The test is based on the behaviour of film when exposed to high temperatures, and on the measurement of the amount of nitrate gases which the film produces in a given time. This test is carried out in the following manner:

Two small punchings of film, of about ¼in. diameter and weighing 7 mg, are taken from the beginning and the middle of a reel, and are each placed in a small glass tube of approximately 85 mm (3½ in.) in length, 11 mm (½ in.) diameter and 8 mm (⅜ in.) internal diameter. Each tube is closed with a stopper (55 mm, 2¼ in., in length) round which is wrapped a piece of test paper, 25 mm by 38 mm (1 in. by 1½ in.), impregnated with alizarin red dye and moistened with glycerine and water. The tubes are heated in an air bath surrounded by a jacket of boiling xylene (C^8H_{10}) which vaporises at 138°C and (allowing for some small heat loss) gives a constant temperature within the bath of 134°C. The film punching at the bottom of each tube is wholly immersed in the air bath, but the upper part of the tube protrudes far enough from the air bath to enable the stoppers and test papers to be completely visible.

This heating of the film punchings indicates the degree of stability of the film by the rate of emission of the nitrate gases which it produces, and these bleach the lower edge of the test paper from red to yellowish white. The result of the test is taken as the time required for this colour change to affect the lower edge of the paper to a width of 3 mm (⅛ in.).

In accordance with the results, action is taken as follows:

Reaction Time	*Action*
Under 20 minutes	Since this represents the greatest degree of disintegration of the film, it must be duplicated immediately, and the nitrate original destroyed.
From 20 to 40 minutes	Retest in 6 months.
From 40 to 60 minutes	Retest in 1 year.
Over 60 minutes	Retest in 3—5 years.†

When the results given by the two punchings do not closely agree, action must be taken according to the lower of the two readings.

This test, which was developed in England and is used by the British National Film Archive and some others with good results, not only reveals the danger of deteriorating nitrate film in good time, but also saves work. It makes it unnecessary to rewind each nitrate film once a year, because under good storage conditions many films may be left untouched for three years and more.

6.15 *Test Notes and Records* Careful notes must be made of all the tests to which a film has been subjected. The results of such tests, together with a record of any damage and imperfection, must be noted in the technical card index. The card

*This has often been called an 'artificial ageing test', but it is more correctly described as a film stability test. (*Publisher's note*)

†Since this Report was completed, the National Film Archive in London, where this test was first used, has simplified its action programme in order to reduce the number of tests and economise in labour, while at the same time slightly increasing the safety margin. It is as follows:
Reaction under 25 minutes: copy on to acetate. Reaction time 25-60 minutes: re-test in one year. Reaction after 60 minutes: re-test in 3 years. (*Publisher's note*)

index must be kept up to date with the results of any retests. The test notes should go to the archivist or his chief technician, so that he can decide if the film is to be treated (see 7.), if it is to be immediately duplicated, or if it can go into storage.

6.16 *Putting Films into Storage* Films destined for permanent preservation should be put into disinfected, dry, clean, undamaged cans. The test cards should not be put into the cans, but should be kept separately.

When there is a considerable difference between the temperatures of the workrooms and of the store (as will always be the case with storage under optimum conditions—see 4.2), the films will have to be left open in a cool room, free of dust, for several hours, to allow them to come into equilibrium with the storage conditions before being stored permanently.

Acetate films which are to be kept in airtight plastic bags must also first be brought into equilibrium with the atmosphere of the store (see 1.333).

6.2 HOW FILMS SHOULD BE STORED

6.21 *The Film Reel* For permanent storage, almost all archives keep their films in metal cans each of a capacity of 1000 ft. Storing in reels of 2000 ft. is also possible, of course, and can even save space; but since 2000 ft. is the length normally used for projection, and exhibition prints are usually stored in 2000 ft. metal cans, a difference in the size of the reels has the advantage that a confusion between reels intended for distribution and films for permanent preservation is less probable.

6.211 It is absolutely essential to wind the films on to cores, and almost everywhere the usual commercial cores, made of plastic or stainless steel with a diameter of 2 in., are used. The Polish Central Film Archive in Warsaw has suggested the use of larger cores, with a diameter of 3 to 4 in., in order to avoid curling at the centre of the reel. The suggestion is a good one, but in many countries these cores are not manufactured, and to produce them only for the use of archives would be prohibitively expensive.

6.212 For permanent storage, the film should be wound with the emulsion side outwards. With the relatively low humidity of a correctly conditioned vault, winding with the emulsion inwards might result in breaking of the emulsion during projection. Projection copies are purposely stored with the emulsion inwards.

6.22 *The Film Can* To prevent the film being damaged by the formation of rust, and to avoid the periodic renewal of cans which this would involve, containers made of a non-corrosive material, such as aluminium, stainless steel or plastic, are to be preferred. Since plastic containers have not yet been available, no one has had experience of their use. Compared with metal cans, ones made of plastic would have the following advantages:

1. They would be absolutely stainless;
2. They would be resistant to acids;
3. They could be manufactured in large quantities, without

increased cost, in the most suitable form (for example, both with ventilation and with airtight seals, as necessary)

In the U.S.S.R., a plastic container for films has been developed, but in order to protect patent rights no particulars are yet available. The containers are at present being tested.

It is not advisable to store film in cardboard cartons, particularly in a store without air conditioning, since the cardboard absorbs moisture and this endangers the film.

Archives which have to use tin-plated ferrous cans should inspect them very carefully for rust, and at the least sign of this they must be changed immediately. Rust can make a film completely useless within a short time. Even to pack the films first in paper does not protect them since rust also affects paper.

The cans used for permanent storage must be cleaned and dried. 6.221
Gosfilmofond in Moscow uses benzine for this purpose and has found that when tin cans are used in air-conditioned vaults no damage by rust has occurred over a period of ten years.

After all that has been said about the properties of nitrate film (see 1.2), 6.222
it goes without saying that such film should never be stored in airtight cans. The cans should never be sealed with adhesive tape, and the ventilation must in no way be obstructed. It must always be possible for the nitrate gases which are formed in the process of disintegration to escape and be carried away by ventilation; otherwise the disintegration will be greatly accelerated (see 1.221 and 1.232).

For acetate film the contrary is true. Since atmospheric oxygen causes 6.223
the release of plasticiser from the base, with consequent brittleness, an improvement is to be expected from storage under airtight conditions. This may be achieved by sealing the cans with adhesive tape, or by first placing the reels of film in plastic bags; once more it should be stressed that a film can only be stored in an airtight condition when it is packed and kept in a constantly steady temperature. Every change of temperature must be prevented, since otherwise the film may be endangered by the condensation of moisture. If these conditions cannot be established, then airtight storage is emphatically not recommended (see 1.333).

Camphor and Oils

In the past it has been a frequent practice to put camphor in the cans 6.23
of films being permanently stored, in order to preserve the suppleness of the film. Indeed, in several archives this is still done. The use of camphor dates from many decades ago, when copies were sometimes projected up to ten times a day. After two or three days, the film became very dry under the constant heat of the projector, so camphor was put in the can overnight, that is to say for a comparatively brief period, in order to restore the flexibility of the film. This was usually repeated after fifty projections.

So far it has not been established that there is any advantage in using camphor in permanent storage. On the contrary, there have been instances of films stored with camphor, for example in the Yugoslav Archive, which showed surprisingly early signs of deterioration, and it is possible that the camphor was a contributory cause. It should

be stressed, however, that there is no certainty about this.

However, the use of camphor is not to be advised. The same applies to the practice of depositing in the cans pieces of paper impregnated with oils, for example glycerine or eucalyptus. As long as there is no scientific proof of the beneficial effect of such measures, it is advisable not to use them.

Packing in Paper

6.24 Many archives wrap their films in paper before storage as a protection against dust and rust. It is not a practice to be encouraged. Porous paper, particularly tissue paper, which presents little obstacle to ventilation, is apt to wear away very easily and in doing so to be itself a producer of dust instead of protecting the film against it. Although smooth paper (e.g. waxed paper) is much more durable, it impedes the ventilation, particularly when the films are tightly wrapped. Only acetate films can be treated in this way. Here the same conditions apply as for packing in plastic bags (see 1.333). Paper does not give any protection against rust, because it is itself attacked by rust, which then penetrates to the film.*

Horizontal Storage on Shelves

6.25 In permanent storage, the film reels must never be stored vertically, but always horizontally. If they are stored vertically, the whole weight of the reel rests upon the lower part of the film. If the film is approaching a stage when it is likely to become sticky, the layers in the lower part are pressed together so heavily that irreparable damage may result.

Complexity of the Storage Problem

6.26 It must be realised that the storage of film is a complex matter, in which various factors have both beneficial and adverse effects. It is impossible, for example, to separate the question of the airtight storage of acetate film from that of the air conditioning of the store, or the question of the preservation of nitrate film from that of ventilation. To achieve the best results in film preservation, all these factors have to be considered very carefully in relation to the existing climatic, technical and economic circumstances.

6.3 SURVEILLANCE OF FILMS DURING PERMANENT STORAGE

6.31 Films which are being stored permanently must be periodically inspected. In general, it may be said that this examination should take place every one or two years, but in the larger archives this is hardly possible. Consequently, a distinction must be made according to the age and condition of the films, which can be ascertained from the record cards.

Negatives, and very valuable positives, should be examined at least every two years. In most archives, other material is examined at

*In accordance with the recommendations made here, the National Film Archive in London now proposes to store its nitrate films in tinned cans between two protective discs of perforated plastic. Those commonly sold as decorative mats for round cakes and gateaux can be bought cheaply and are very suitable for the purpose. (*Publisher's note*) longer intervals (the longest interval reported is six years). Such long periods are only permissible for new films being kept under very good storage conditions; with old negatives or positives they are dangerous. The interval for re-examining nitrate film is determined by the results of the film stability test (see 6.14).

Rewinding In principle, the examination consists of rewinding the film on the winding table, and at the same time, during the first examination, cleaning it from dirt and dust. It is immaterial whether the film is wound by hand or electrically, but it is important that the winding is done sufficiently slowly to enable an adequate examination to be made (about 2000 ft. an hour: see 6.111). 6.32

Notes should be made of the results of each check. If no new damage is discovered which requires remedial treatment, the film should be immediately returned to the store.

Checking for Use Films intended for permanent storage should never be used for projection. If, however, a negative or a print is used for copying or viewing, then it is essential that its technical condition should be checked again by a technical inspection before and after use. 6.33

Film Stability Test The film stability test is not an automatic part of the examination, since it is applicable only to nitrate film. 6.34

Cleaning and Restoration The films are only cleaned during examination when their condition makes it necessary. The same applies to all other measures. 6.35

PRESERVING MAGNETIC RECORDINGS Under 2.423 it was stated that at present the safest method for permanent preservation of recordings on magnetic tape was to have them duplicated on to optical film. If magnetic recordings have to be stored in their original form, they should be treated as acetate film (see 3.6). This means that they can be kept in acetate film stores (on wooden, not steel racks—see 2.422), and it is necessary to protect them against the influence of electro-magnetic fields (see 2.421). The cans should be tightly closed to prevent the penetration of dust (see 1.333). No special preparatory treatment of magnetic tapes before storage is necessary. During storage, they should be moved and examined as little as possible. Tapes which have to be reproduced should, as has already been said, be duplicated on to optical film as soon as possible. 6.4

7. THE RESTORATION OF FILM

7.1 A distinction must be made between the technical restoration of film, and the restoration of its content. TECHNICAL AND EDITORIAL

7.11 Editorial restoration, namely putting a film back into its original form as a work of art or a document, involves the replacement of any parts which may have been lost and the correction of the cutting. Such work can be carried out: with the help of any records which may have survived, particularly editing notes, title lists or shooting scripts; by comparing the film with versions held in other national archives; and, as far as possible, by consultation with those who were concerned in the production of the film. The editorial restoration of great films is a most important task for every film archive, especially in relation to its own national film production.

7.12 Here, however, we are concerned solely with the technical restoration of negatives and positives, and with the elimination of physical and chemical defects and damage, in order to make them fit, in respect of both picture and sound, for copying and exhibition. Technical restoration must precede editorial restoration, since it is only after the film has been technically restored that a full survey of the content can be carried out. The decision as to what remedial measures shall be taken is one which must rest with the archivist after consulting the examination notes (see 6.15) and inspecting the film.

7.2 Film material which has suffered irreparable damage, so that projection copying is no longer possible, is completely worthless. Any attempt at further preservation is pointless, and there is nothing to do but destroy the material. Examples of such irreparable damage are as follows: IRREPARABLE DAMAGE

7.21 Nitrate film in the last stages of disintegration (in which the emulsion is softened and blistering, the film sticks together, and the base is totally disintegrating—see 1.221, (iii)–(v)) is beyond salvation and must be destroyed immediately. There is no treatment which can make it suitable again for projection or copying. *The Advanced Disintegration of Nitrate Film*

7.22 When a film has lost flexibility, as the result of the loss of plasticiser and the moisture of the gelatin, it breaks on rewinding, and is incapable of further projection. There is no way of restoring the flexibility, even in a humidifying cabinet. *Extreme Brittleness*

The Fading of Colour Developed colour films have only a relatively short life (see 1.441). 7.23
The colours fade and eventually disappear. Negatives and copies of which one or more colours have disappeared cannot be copied or projected. The damage is irreparable, because there is no way in which the colours can be restored.

Damage to the Picture by Fungus When the emulsion has been attacked by fungus which has penetrated 7.24
so deeply that part of the picture has been eaten away, this damage also is irreparable.

DAMAGE WHICH CAN BE REPAIRED Examples of damage which can be treated more or less successfully 7.3
are dirt, spots, scratches on the celluloid and emulsion side, brittleness, residual chemicals, tearing of the perforations, stickiness and bleaching of the silver image. Much of this very delicate work has to be done by hand; some can be done by specially designed apparatus.

Dirt Dirt is removed (see 6.12) with chemical solvents, in the application 7.31
of which machines are generally used. The ultrasonic machine is preferable to the more traditional methods because it is kinder to the film.

Individual Spots Single spots are not removed by machine, but are cleaned off by hand 7.32
on the winding table. For this purpose the following substances may be used:

acetone—to remove spots of film cement or acetone;
carbon tetrachloride—to remove oily dirt;
ethyl alcohol—to remove dirt which is not oily.

Abrasion Abrasions and scratches, which are caused during projection, or as the 7.33
result of inexpert handling during rewinding of the film (which is very susceptible to mechanical damage), can be removed when they are not too deep.

Scratches on the celluloid side can be removed by polishing. The 7.331
principle here is always the same: the surface of the celluloid side is softened by moistening with acetone, and then drawn over a glass roller under pressure. In this way all the scratches and abrasions are removed. After this treatment the celluloid side of the film is completely flawless. The polishing is done by machine. There are two systems: in one, a revolving glass roller, with a diameter of 6—8 in., dips into a bath of acetone and thereby moistens the base of the film, which is pulled over it under pressure; in the other method, acetone is dripped or sprayed on to the film, which is then pulled over a glass roller with a diameter of only half an inch. Both methods produce good results. The second system, which was developed in Prague, has the advantage that the film can be fitted with clips to prevent the joins coming apart in the machine; consequently this sytem lends itself to use in a combined restoration machine.

Abrasions and scratches on the emulsion side can be removed by 7.332
causing the emulsion to swell; the film is soaked in water, and then dried. For this operation one can use machines which may be rebuilt, without great expense, from old small developing machines, as long

as they are free from corrosion. In the State Film Archive of the German Democratic Republic such a machine has been used successfully for many years.

Deep scratches cannot be removed in this way. They require the application of a very thin protective layer or coating of acid-free wax or lacquer, applied mechanically. To attempt to use for emulsion scratches a similar method to that described in 7.331 for scratches on the base, namely to soften the emulsion by soaking and then to subject it to pressure between rollers, is emphatically not to be recommended. Certainly scratches can be eradicated by this means, but it is injurious to the picture. The exertion of pressure on the softened emulsion deforms the contours of the image and results in a loss of picture quality.

7.333 The methods described here for the removal of scratches and abrasions are very important; they improve the quality of the film, and make it possible to print relatively good copies or duplicate negatives. During the last few years, however, there has come into use a method of duplicating which makes preparatory treatment of scratched material superfluous; it is called the anti-scratch process. The original scratched material (negative or positive), before entering the printer gate of an optical printer, is automatically covered on both sides with a liquid which has exactly the same refractive index as the base. The scratches in the original material are not copied on to the new print, because the printing light passes directly through the original material without any deflection of its rays by scratches or particles of dust. In this way a scratch-free copy can be printed from a scratched original. Such optical printing machines with anti-scratch installations have been made in several countries, and for archives which have their own printing laboratories they are one of the most important pieces of equipment.

7.34 *Residual Chemicals* The removal of residual chemicals is imperative, because film material which has not been properly developed and fixed will be ruined during storage.

7.341 The only successful treatment for incomplete fixing is to have the film re-fixed and thoroughly re-washed.

7.342 It often occurs, however, that the film has been properly fixed, but not sufficiently washed afterwards. In this case a residue of the fixing salt (sodiumthiosulphate, also called hypo) is left in the emulsion. This, like other sulphur compounds, will in time bleach the image. It is therefore recommended that new films, as they are acquired, should be tested for the presence of any hypo in the emulsion. The test is as follows:

In a test-tube a solution is made up of

mercuric chloride	25 gms
potassium bromide	25 gms
water to	1 litre

Into this solution is put a piece of film (one frame of negative, two or three frames of positive, because of the difference in thickness of the emulsion layer), cut into strips of a suitable size. With even a very low content of hypo (0·05 mg.) the solution quickly turns milky and turbid. The degree of turbidity depends upon the amount of hypo in the emulsion.

It is also possible to cement a punching of film (base down) on to a piece of plain acetate base. When it is dry this piece of film is laid down on a black background, and a drop of the above-mentioned solution is placed on the punching of the film to be tested. If hypo is present, the drop becomes turbid within three minutes. This method has the advantage that the film does not need to be cut.

Whichever method is used, when the mercuric chloride solution becomes turbid this is an indication that the film must be thoroughly rewashed. There is no exact rule for the duration of this washing, but a minimum of half-an-hour is generally considered necessary.

Brittleness Bad storage conditions, particularly an excess of warmth from dryness, 7.35
can cause a film to lose flexibility. A slight brittleness is the first sign of a growing brittleness which will eventually become irreparable.

In the long run, the flexibility of a film can only be maintained by good storage conditions (see 4.2). Once brittleness has started to appear it can be reversed only temporarily in a " filmostat ", but this may be enough to enable the film to be duplicated. The brittle film is wound loosely and placed, without a can, on a stainless steel grating in a humidifying cabinet. In the bottom, or at the sides, of the cabinet are containers with cotton-wool soaked in the following solution:

acetone	15 gm
glycerine	25 gm
water	60 gm

This volatile solution is extremely effective in enabling the film temporarily to regain its original flexibility.

Shrinkage The shrinkage of film is usually a result of storing it in conditions 7.36
which are too dry and too warm. The dimensions of the film change, the image becomes smaller and the interval between perforations is shorter. Film which has shrunk beyond a certain point can no longer be used on normal machines and apparatus. Shrinkage is irreversible.

It is nevertheless possible to save the film by making a new copy of 7.361
standard dimensions on a step printer. In one form of such printer the shrunk film is passed over an opal glass window which is illuminated from the rear. With a 35mm cine camera it can then be photographed frame by frame. Basically, this is 1 : 1 optical printing. The shrinkage is compensated for by regulating the distance from the objective to the image. Correction of the image is possible vertically, horizontally and by tilting. The film is moved by hand over rubber rollers, without the use of sprockets. Simple apparatus of this kind has been used for a number of years in the National Film Archive in London and the Netherlands Film Museum in Amsterdam, with excellent results. A considerable number of films of historical value have been saved in this way: for example, many of the first Lumière films.

The same results can, of course, be achieved with a modern optical printer, provided that it is fitted with a sprocketless film transport

mechanism. The cost of such a machine is much greater than that of the apparatus we have just described.

7.37 Stickiness is either a sign of the advanced disintegration of nitrate *Stickiness*
film (see 1.221) or may be the result of storage in over-moist conditions (see 1.421 and 1.422). Layers of sticky film should not be separated while dry. Such films must be unwound by hand under water with the greatest care. The only requirement is a very simple article, namely a large bath, in which the film can be softened and from which it can be wound on to a drying cloth or passed through a drying cabinet. Unfortunately, when film is very sticky, it is sometimes impossible to avoid removing some of the emulsion from the base, despite the greatest care.

7.38 If the silver image has discoloured under the action of nitrate gases *Discoloration of the Silver Image*
or residual chemicals (see 1.43), continued preservation of the film is only worthwhile if the density can be restored. This is possible, but the process is complicated, so it is advisable to have it done in a suitable laboratory. The discoloured silver image is first bleached, and then redeveloped. Where the discoloration has gone very far, this process has produced some very disturbing colour variations. In the German Democratic Republic, a new process has been developed, and is being patented, which makes restoration possible even in cases which were formerly considered hopeless.

7.39 Severe tears to perforations, which may even extend into the image *Damage to Perforations*
area, present an obstacle to the copying of a film. Single broken perforations can be cut out, and the corners must then be rounded. Greater lengths of damage must be cut away, and new perforations cemented in their place. This work must be done very precisely and is therefore extremely time-consuming. Where the perforation intervals are still of standard size, transparent perforated Permacel can be applied to the damaged parts over the whole width of the film.

7.4 A WARNING AGAINST "SECRET" PROCESSES

We cannot warn too strongly against the treatment of film by so-called " secret " processes, outside the control and knowledge of the archive. It is essential to know exactly what a film is being treated with, and to be quite sure that this treatment can have no harmful consequences. The coating of films, for example, with this or that special wax or lacquer, the composition of which is not made known, carries with it the danger of chemical changes in the film material itself, which may not be noticeable at first, but which can in the long run lead to the complete destruction of a negative or print.

7.5 HAND AND MACHINE WORK

7.51 Some kinds of restoration work are much better done by hand than by machine: for example, the separating of sticky film, the removal of single spots and the repair of perforations.

7.52 For other operations, appropriate machines have been developed: for example, for washing (see 7.332), cleaning (see 6.12), polishing (see

7.331) and coating (see 7.332). The use of such machines provides a significant increase in working capacity, even when, to safeguard the film, the machines are run slowly (e.g. 600—2000 ft. per hour).

It is even more efficient to have all the processes performed by a single machine. Gosfilmofond in Moscow has developed restoration machines (one for negative and one for positive) which in one passage of the film clean, soak, refix, remove residual chemicals, coat and polish it. In this way a film can be treated thoroughly, with the expense of comparatively little labour and time. Gosfilmofond describes the operational procedures of the machines as follows: 7.53

Washing and Regeneration of the Emulsion of Negatives:

(*a*) Preliminary wetting	4 mins.
(*b*) Re-fixing	4 mins. in a 25% solution of sodium hyposulphite.
(*c*) Intermediate rinse	7 mins. in water.
(*d*) Soaking of the emulsion and removal of residual hypo	4 mins. in a 0·3% solution of ammonia.
(*e*) Cleaning with rotating rollers of chamois leather	
(*f*) Final washing	17 mins. with water.
(*g*) Drying	43 mins.

By washing and soaking the emulsion and subsequent drying, all minor scratches caused during exhibition or inspection are eliminated. Deeper scratches cannot be removed in this way. This is achieved by application of wax or lacquer. Gosfilmofond has this application of a protective coating on negative emulsion done by a special machine.

Washing and Regeneration of Positives:

(*a*) Cleaning off grease with the aid of a soap solution (OP — 7), or a mixture of 50% carbon tetrachloride and 50% benzol applied with rotating chamois leather rollers.

(*b*) Soaking	35 mins. in 0·3% solution of ammonia.
(*c*) Rinsing	3 mins. in water.
(*d*) Cleaning the emulsion with rotating chamois leather rollers.	

(*e*) Application of a lacquer to the emulsion (protective layer) with a 4% solution of polyvinyl alcohol in water.

(*f*) Drying 21 mins.

(*g*) Polishing of the base with acetone.

All these processes are carried out by only one machine (when necessary, one or more of the processes may be omitted). This machine works at a speed of 1300—2000 ft. per hour.

Negatives or positives which are affected by fungus, mildew or the like are also treated in these machines. Before drying they are moistened for a minute with a 1% solution of sodium trichlorophenolate.

Similar machines are in use in the Czechoslovak Film Distribution laboratories in Prague. A restoration machine incorporating an ultrasonic cleaner is under construction at the State Film Archive of the German Democratic Republic.

8. QUALIFICATIONS OF PERSONNEL

8.1 The preservation and restoration of an archive film collection is a responsible task which cannot be carried out except by personnel properly instructed and experienced in this special field. Failure to employ qualified staff has already cost some archives the loss of important parts of their holdings.

8.2 In large archives, with correspondingly large numbers of employees, the senior technicians should be graduate chemists or engineers. They are responsible for all the technical processes: the inspection of films before storage, periodic testing during storage, film restoration, the control of duplicating machines and the further development of machines and working methods. At present, only a few archives have a staff of technically qualified personnel such as we have just described. This is the more regrettable because it is only to such people that we may look for improvement and development in the machines and procedures which are necessary in this specialised field.

8.3 The technical assistants directly responsible for such work as the control of plant or operation of machines should have had training in similar work (e.g. as film laboratory workers, mechanics, etc.). The technical employees of most archives have received only such limited practical training as they can obtain in the course of their day-to-day work. One of the aims of F.I.A.F., through the work of its Preservation Committee, is to give them a broader view of their field of work, since the future development of film archives is dependent on their having the widest possible knowledge and experience.

8.4 Hitherto, international co-operation between the film archives in all countries has consisted in making use of their collections for organising retrospective film performances and exhibitions, and in enlarging their collections by the exchange of films. From the firm basis thus established, international co-operation must now be extended to the field of film preservation. A first step towards this end was the establishment of the international Preservation Committee; the publication of this Report is a second. The next step should be the sharing of experience between neighbouring archives, and this can best be done by an exchange of qualified personnel for predetermined periods. The work of our Preservation Committee has demonstrated that the larger archives have no desire to keep their knowledge and experience jealously to themselves, but are willing to put them at the disposal of other countries. In the State Film Archive of the German Democratic Republic, and in the National Film Archive in London, some colleagues from abroad have already received a few months' training, and to-day they have responsible positions in the archives of their own countries. No doubt other archives have done the same. It is to be hoped that this kind of exchange and the pooling of experience will be practised increasingly, to the benefit of all archives.

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