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Moving Images: Conservation and Preservation

INTRODUCTION

October 6, 1993 will mark the 100th anniversary of the first U.S. copyright registration of a motion picture. It was registered under the title Edison Kinetoscopic Records, but there is no known copy of the film, nor is it known what images it contained. That this significant first in film history did not survive is not only symbolic of the fate of thousands of films in the past, but also of that which may yet await the majority of the moving images produced today. Although the chemical composition of nitrate motion picture film is inherently unstable, in many ways a greater threat to the survival of these films was the attitude of producers and public alike. Films were considered as mere entertainment with no importance beyond immediate commercial exploitation. As a result of many years of deliberate destruction, neglect, fire, and deterioration, over half of the motion pictures produced before 1951 no longer exist.

Today, there is an awareness that moving images are the most vivid and compelling records of history and are a powerful force in shaping culture. While this heritage must be preserved, the challenge of doing so is enormous. An estimated 90 million feet of uncopied nitrate film in U. S. archives has yet to be preserved—and there are millions of feet of fading color films; thousands of unprotected independent, educational, industrial, and amateur films; and vast quantities of unpreserved television news and entertainment programs. If even a portion of these moving images are to be safeguarded, there must be an awareness of the scope of the problem and a recognition that the responsibility for preservation is shared by producers, archives, libraries, historical societies, and film and video study centers. Every institution holding moving images has an obligation to protect this material for future generations. Every year, more and more institutions are recognizing their own role in what is—and must be—a national preservation effort.

The movement to archive films began in the United States with the pioneering efforts of the Museum of Modern Art (MoMa). MoMA began in the 1930s to collect and preserve films as works of art and was a founding member of the International Federation of Film Archives (FIAF) in 1938. The National Archives and The International Museum of Photography at George Eastman House soon joined in the preservation effort. The Library of Congress, which received films as copyright deposits until about 1912, began to acquire films for the motion picture division in the mid-1940s and established a preservation program in 1958. Although the efforts of these archives were considerable, much of early cinema had already been lost.

In 1967, the American Film Institute began a nationwide effort to locate and acquire nitrate films for preservation. To assist in this effort, the National Endowment for the Arts established the AFI/NEA Film Preservation Program to fund the conversion of nitrate film to safety stock. Over the next twenty years, many thousands of early films were saved through the combined efforts of the major archives. Over 21,000 nitrate films were acquired for the AFI Collection at the Library of Congress alone. But the problem of moving image preservation grew with the times. Archives became more and more concerned about the many other types of unprotected films and the problems presented by the preservation of television programming. The National Center for Film and Video Preservation was founded in 1983 and continues the activities of the AFI Archives Program in the areas of film acquisition and the publication of the *AFI Catalog of Feature Films*. The Center is committed to serving as an instrument of national coordination and is designing and implementing a National Moving Image Database (NAMID) which will eventually provide data on film and television holdings at archives, studios, and networks as a tool for preservation.

The need for coordination in moving-image preservation has been recognized for many years. In the late 1960s, major institutions involved in nitrate preservation established the Film Archives Advisory Committee (FAAC) in order to avoid duplication of efforts and to ensure that the best possible copies of films were being preserved. In the late 1970s, institutions involved in television preservation formed a similar group (TAAC), and eventually the two were combined into the Film and Television Archives Advisory Committee (FAAC/TAAC). FAAC/

TAAC is an informal organization, with no constitution, no rules and regulations; all institutions with film or video collections are invited to join. Meetings are held once a year and are attended by individuals from about seventy institutions. Presentations on topics of interest, such as technical developments in film and television preservation or standards for cataloging of moving image materials, are always included in the program. FAAC/TAAC also has working groups devoted to special purposes, such as independent film and television news. The National Center serves as the secretariat for FAAC/TAAC and publishes a quarterly newsletter on archival activities. (More information on FAAC/TAAC is available from the National Center for Film and Video Preservation at the American Film Institute, P. O. Box 27999, 2021 North Western Avenue, Los Angeles, CA 90027. Their phone number is (213) 856-7637).

PRINCIPLES OF PRESERVATION

The dictionary states that to preserve means to keep safe from injury or harm; to keep or save from decomposition; to keep alive, intact, or free from decay (Webster's New Collegiate Dictionary, 1973, p. 910). To preserve a film or videotape, it is certainly necessary to safeguard it from chemical or magnetic destruction; and, since the "moving" of moving images is provided by equipment which can damage or destroy them, they must also be protected from unwarranted use. Thus the preservation of a film or videotape cannot be considered secure unless a master copy is held by an archive. This is a general principle which has been advocated by the International Federation of Film Archives (FIAF) and one to which the major archives in the United States subscribe.

In practice, this principle means that moving images should not be used as reference copies until master material is preserved in a public institution. In these days, when video outlets abound throughout the country, the need to be so concerned about preservation may seem a bit remote. However, many times in the past a shrunken, scratched, and overprojected print has proved to be the only copy of a Hollywood feature that was once distributed nationwide. Locally produced films or television programs have an even greater chance of being unique and unprotected copies.

The first step in any archival program is to identify the material and determine its preservation status. It should be noted here that it is extremely unwise to identify films by running them on a projector.

Using hand rewinds and a manually driven viewer (or magnifying glass) is the only truly safe method.

Any unique films should be protected by negatives or master positives; copies of unique videotapes should be made for reference use. All original materials should be retained whenever possible and should be stored under appropriate archival conditions. In addition, any film or videotape—even if it is not a unique copy—needs special care and storage.

Film

Although some rare development processes have been used for motion pictures, the images in most films are formed from the reaction of silver halides with light. The silver halides undergo a chemical change when exposed to light; an image is formed in the development process and is then fixed to make it permanent. The basic structure of film consists of three layers: the image layer, composed of a gelatin emulsion in which the silver halide crystals are suspended; the substratum or binder (sometimes also called the adhesive or substrate layer) which enables the emulsion to adhere to the third layer, known as the support or base. All three of these components present problems for conservation and preservation, but the problems presented by the base will be the main concern here. (The preservation of color films is the subject of another presentation and will not be addressed in this report).

Cellulose Ester Films

Esters are simply compounds which are formed by the reaction of an acid and an alcohol. Most film bases are esters of cellulose, a naturally occurring substance found in cotton, wood fibers, etc. Cellulose ester base is manufactured in a process known as solvent casting in which cellulose fibers are esterified with acid (a preparation usually referred to as the "dope") and combined with other ingredients such as plasticizer and fire retardants (Sargent, 1974; Lee & Bard, 1987, 1988). This mixture is then dissolved in alcohol and spread on a heated, rotating drum. The heat causes the alcohol to evaporate, and the result is a thin sheet of transparent film which can be stripped off the drum and prepared for emulsion coating. Cellulose ester films are named according to the type of acids used in the manufacturing process, i. e., cellulose nitrate, cellulose triacetate, and so forth.

All layers of motion picture films are hygroscopic, that is, they absorb moisture. If too much moisture is absorbed, the film undergoes hydrolysis and begins to break down. On the other hand, if conditions are too dry, the plasticizer compounds, which provide flexibility, can evaporate and the film will shrink, buckle, and become brittle. In addition, the chemical composition of each type of cellulose ester film causes particular problems.

Nitrate Film

Cellulose nitrate film —in which the cellulose was esterified with nitric and sulfuric acids—was the standard for 35mm theatrical motion picture film from the beginnings of the motion picture industry until 1951. There is a great deal of published information about nitrate film and many people are familiar with its characteristics even if they have not handled it personally.

Although it is a surprisingly strong and durable substance, nitrate film is chemically unstable and deteriorates in a process which is both inevitable and irreversible. Nitrate is also highly flammable. It is not explosive, but deteriorated film has been shown to self-ignite at temperatures as low as 106°F. Once ignited, a nitrate fire burns extremely rapidly and is impossible to extinguish. Burning nitrate also gives off toxic fumes which can be fatal if inhaled.

Decomposition of nitrate film really begins from the date of its manufacture. Obviously, this can be a very slow process since there are films over eighty years old which are still in good condition.

However, unless a means to arrest the decomposition process is discovered—which is unlikely—all nitrate film will eventually completely deteriorate. Storing nitrate film properly enhances its longevity, thus buying time to copy it onto a more permanent medium.

In the first stage of nitrate decomposition, the image begins to fade or discolor and the film begins to emit a pungent odor. As the process advances, the emulsion begins to soften and the film becomes brittle and sticky. The image then disappears entirely and the film becomes either a solid, almost glasslike mass or, sometimes, a viscous black sludge. Ultimately, the film degenerates completely into an acrid brown powder.

Any films in the last stages of deterioration should be considered hazardous and should be placed under water in steel drums or other suitable containers until they can be disposed of properly. However, it should also be noted that sometimes a thin layer of nitrate powder can appear on top of a film which is otherwise in good condition. It is also possible to mistake rust from the film can or reel for nitrate deterioration. One should not become alarmed and throw films out by mistake.

As nitrate decomposes, it releases nitrogen oxides which accelerate the decomposition process and can harm other nitrate and acetate films in the area. Decomposition is also accelerated by heat and humidity. The film must therefore be stored in cool, dry conditions with sufficient air circulation so that the gases released do not accumulate. Nitrate should be stored in a segregated area with its own air supply so that nitrogen oxides cannot affect other films.

The generally recommended temperature for archival storage of nitrate is between 35° and 50°F., with a humidity range of 40 to 50 percent (Bard et al., 1983). It is difficult to achieve low temperatures without increasing relative humidity, so some institutions have had to be satisfied with a temperatures somewhat above 50°F in order to maintain a humidity level of not more than 50 percent, but in no case should nitrate be stored at a temperature of more than 70°F. Fluctuations in temperature and humidity should also be avoided. Experience has shown that when films have been subjected to wide fluctuations in temperature and humidity, they can begin to deteriorate very rapidly. Newly acquired films which have been exposed to such fluctuations during shipping should therefore be inspected frequently, and all nitrate film should be inspected at least once a year. Inspection involves more than just opening the can. Each reel should be wound slowly from end to end and, if deteriorated sections are found, the film should be copied immediately. If this is not possible, the deteriorated sections should be cut out to keep them from infecting the rest of the reel.

Nitrate storage must also conform to fire codes and meet established safety standards. A few reels may be kept in fireproof cabinets, but any substantial quantity of nitrate must be stored in a specially constructed vault. Most institutions do not have such facilities and rent space in commercial vaults. Organizations with only a few reels of nitrate may be able to find space on a cooperative basis with one of the major archives. (More detailed information on regulations for storing nitrate is available from the National Fire Protection Association in Quincy, Massachusetts.)

It is illegal to send nitrate film through regular mail, but if packed and labeled according to regulations, it may be shipped via Federal Express, UPS, and other surface and air transport. As a flammable solid, nitrate is classified as a hazardous material and regulations for packing and shipping may be obtained from various transport companies. Nitrate should not be shipped in the summer or at anytime when the outdoor temperature is above 70°F. Nitrate in an advanced state of deterioration should *never* be shipped. Again, film in this condition should be placed in a container filled with water until it can be disposed of properly. One should consult with local fire authorities for regulations about proper disposal.

One of the problems with 35mm film is that it is not always easy to determine if it is on nitrate stock. For many years, some manufacturers printed the words "nitrate film" along the edge, but not all films from all manufacturers were marked in this way. Unmarked nitrate can be identified by dropping a small clip into a bowl of trichlorethylene; however, trichlorethylene has been classified as a carcinogen, so this method is now rarely used.

Some people resort to the burn test, i. e., to clipping a very small piece of the leader or a tiny strip from along the edge and lighting it. If used, this test should always be done out of doors and never near the reel of film in question. In general, for all 35mm films which are known to be produced prior to 1952, it is best to treat them as nitrate until they are identified otherwise (Eastman Kodak, 1969). Although some 16mm films on nitrate base have apparently been found, 16mm film was never manufactured in the United States on nitrate base and the chances of running across it are extremely slim.

Acetate Film

The term *acetate* is often used generically to describe all safety film, but in fact, there are several kinds of acetate film such as cellulose diacetate, cellulose acetate propionate, and cellulose triacetate. Work to develop a nonflammable film was begun very early and a safety base film was available in 1908. Early safety films were not suitable for commercial purposes because they were neither strong nor flexible enough to stand theatrical use and they had poor geometric stability, i.e., they shrank, often dramatically. Safety film was therefore confined to educational and amateur use and was manufactured in 9.5mm, 28mm, and other nonprofessional gauges. Some of these nonstandard gauges are a special problem because of the scarcity of equipment on which to copy them. 16mm film, introduced in 1923, remains in common use today.

The most common problem of early safety film is that the plasticizer has been lost to such an extent that the film is far too brittle to withstand projection and sometimes cannot even be unreeled without breaking into pieces. It can also become so shrunken that it curls into a tube shape, making it nearly impossible to copy.

Early safety film, diacetate in particular, often exhibits an even more serious problem in that it can disintegrate in a manner not unlike nitrate—the image fades, the base softens, and the emulsion separates from the base, giving the film a "crazed" or cracked appearance. Sometimes a deposit of white powder is formed. This usually means the film is undergoing autocatalytic hydrolysis and has absorbed moisture to the point where it begins to break down. The acetic acids used in the esterification process are released and, as acid is produced, the process of disintegration continues at an ever faster rate. Films disintegrating in this way exhibit a characteristic odor of acetic acid, which has given rise to the name for the problem: the *vinegar syndrome.*

Cellulose Triacetate Film

Cellulose triacetate film first became available for widescale commercial use in 1948. It had the strength, flexibility, and dimensional stability required for commercial use, and the manufacture of nitrate film was discontinued in 1951. Cellulose triacetate is an archival medium and is used for virtually all preservation copying. Tests have shown that, if properly stored, cellulose triacetate should last for hundreds of years.

Recently, however, examples of vinegar syndrome in triacetate film have been found which have caused concern among the archivists (Brems, 1988). Thus far, vinegar syndrome has been found to be a particular problem in hot and humid climates. It is, therefore, reasonable to associate vinegar syndrome with poor storage conditions. Since most institutions often receive films which have been stored under adverse conditions, it is necessary to recognize and guard against the problem. There are a number of research projects currently underway to identify the causes of vinegar syndrome and, if possible, to find a way to stabilize the deterioration process. However, until we know more about the process of acetate deterioration, the only hope for films exhibiting vinegar syndrome is to copy them onto new stock. Films with vinegar syndrome should also be isolated since the vapors given off can infect other films as well. Since evidence indicates that humidity may be the most important factor in causing vinegar syndrome, the humidity level of storage areas should be carefully controlled.

While proper storage has always been a basic component in archival preservation, recent concern about all forms of chemical decomposition has made archivists even more aware that proper storage is absolutely essential for the preservation of moving images. Generally recommended standards for archival storage of black-and-white motion picture film are no more than 70°F with a humidity range of 30 to 50 percent.

Polyester Film

Polyethylene terephthalate (PET) film, usually simply called polyester, has been an alternative to triacetate film for a number of years. Polyester was invented in 1941. It was developed for use as a film base after World War II and is widely used for small gauges such as 8mm and also for professional 35mm film. Polyester is also the standard support layer for videotape.

Since polyester is insoluble in most common solvents, this film base must be manufactured in a process known as *melt casting* (Sargent, 1974; Lee & Bard, 1987, 1988). Molten polyester is extruded onto a casting cylinder and then stretched in both width and length and "set" by heating. Studies have shown that polyester base has a stability equal or superior to triacetate film.

Polyester film has been proposed by many experts as the ultimate answer to film preservation. However, it has a number of drawbacks which have thus far made archivists shy away from it. One difficulty is the inability to splice it using conventional solvent methods; it must be spliced using either tape or an ultrasonic splicing device. It can also exhibit a phenomenon known as "core set" in which the film sets into an irreversible curl after having been wound around a narrow core in storage.

A more difficult problem is that the majority of films manufactured today are color stocks and most archival work is done in black and white. Appropriate negative and positive emulsions are not easily available in black-and-white polyester stock. In addition, polyester film originally presented problems in the adhesion of the emulsion to the base and, while the emulsion coating technology has improved since polyester film was first introduced, many archivists are not yet confident that the emulsion will adhere to the base on a long-term basis. Since polyester is an exceptionally strong material, it presents an attractive alternative to triacetate film for commercial use, and no doubt many films on polyester will be coming into archives. For the present, most archivists feel that more research on the adhesion characteristics of polyester needs to be done before it can be accepted as a standard for archival work (Brems, 1988).

Videotape

To many film archivists, videotape is extremely frustrating—one cannot simply hold it up to the light to see what images it contains. And herein lies the root of the difficulties for its preservation. Since videotape is not a human-readable material, it is totally dependent on appropriate equipment to retrieve the sounds and images it carries. Videotape is not considered an archival medium for several reasons. It can be very easily erased or altered. Moreover, the surface of the tape itself is abraded each time it passes over the heads which read the information. Videotape is also a relatively new medium and it has not been demonstrated to be a permanent one. Finally, experience has already proven that, even if videotape itself were to last hundreds of years, it would far outlast the equipment on which to play it.

Videotape was first introduced as a professional recording medium in 1956. In physical structure it consists of a thin substrate or base layer of polyethylene terephthalate (PET). On top of this base is a polymeric binder layer (usually from a class called polyester polyurethanes) in which magnetic particles are embedded. Some tapes also have an additional layer called backcoating, a polymeric binder in which carbon particles are imbedded.

Videotapes are subject to various forms of defects such as drop-out, a loss of picture or sound information in certain areas of the tape; print-through, in which information on one layer of the tape is transposed onto an adjacent layer in the tape pack; and various technical problems such as timing errors made at the time of recording. Many defects in videotape tapes are caused by physical damage from dust and dirt or creases in the tape caused by uneven winding. To avoid some of these defects, tapes should be used and stored in a clean environment. Tapes should also be stored on edge in a container which supports the tape reel at its hub, and should be wound slowly from end to end before storage.

Both the base and binder layers of videotape are subject to physical degradation from hydrolysis, which can cause the molecular structure of the polymeric materials to break down. Recent research also indicates that the binder is particularly susceptible to degradation when exposed to high humidities (Calmes, 1988).

The optimum recommended storage for videotapes is 60°F with a relative humidity of 25 percent. Since it is sometimes difficult to control humidity, storing tapes in vapor-tight bags may be an alternative. However, not enough is yet known about the properties of videotape cassettes and other containers and how these might affect the tape in micro-environment storage. In the meantime, storage conditions should follow the recommendations as closely as possible with an emphasis on maintaining low humidity. In addition, if tapes are used under different conditions from which they are stored, they should be allowed to equilibrate in the use environment before playing.

Whatever the problems presented by videotape composition, a far more serious difficulty is the great variety of incompatible tape formats and the growing obsolescence of the equipment on which to play them. In some cases, equipment for formats less than ten years old is not only already hard to find but also extremely difficult to maintain because spare parts are not available. Manufacturers do not continue to support the technology of outdated formats and, as technology and equipment become more sophisticated, this problem will continue to grow.

In order to preserve the information on videotape, it seems that there is little choice for the archive except to conserve tapes in proper storage and copy them onto newer formats every ten to fifteen years or so. An alternative to continued recopying of videotape, albeit an expensive one, is to copy videotape once—onto film. The technology for motion pictures is relatively simple; even in the event that film becomes an outmoded format, it should always be possible to construct projection equipment. Each archive will have to weigh the one-time expense of making film copies versus the continued expense of recopying from tape to tape. Another consideration is that in the current analog recording method, quality is lost with each succeeding generation. Digital recording holds the promise that tapes may be copied over indefinitely without loss of quality, but increasing complexity of the equipment is bound to create more problems in regard to availability and maintenance. In this sense, digital recording may be both a blessing and a bane.

Optical Disc Recording

Optical disc recording at first seemed to indicate that it would be the answer to permanent preservation for the archive. However, discs themselves are not a proven archival medium, and there have already been some examples of physical deterioration. Moreover, the problem of technology is even more vexing than that of videotape. There are over ten incompatible formats in current use, and it is to be expected that things will get more, not less, complicated. Storing moving image information on discs is excellent for quick reference and retrieval, but it cannot be considered an option for permanent preservation at this time.

CONCLUSION

The cost of film and video preservation is high, ranging from about one dollar and up per foot of film to $100 and up for each hour of videotape. This makes it all the more necessary for the archive to ensure that it is getting the best possible quality in its preservation masters. There are only a few commercial labs in the United States which specialize in copying nitrate and/or problematic safety film. Recommendations about them may be obtained from the National Center or one of the major archives. Many commercial labs can assist with general film or video copying, but if a particular lab has no experience in archival copying, it is wise to work closely with lab personnel to ensure standards of quality.

The task of preserving moving images is a difficult one and requires time, effort, and money. The problems to be faced are serious ones and the situation, particularly in regard to technology, is not getting any better. Hopefully, one day the perfect preservation medium for all moving images will be developed. In the meantime, archivists must continue to do the best they can with the materials at hand. Through the combined efforts of many institutions cooperating on a national level, it is possible to meet the challenge of preserving our moving image heritage.

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