A. Abrizah, et al. (Eds.): ICOLIS 2010, Kuala Lumpur: LISU, FCSIT, 2010: pp 223-232

Restoration and preservation of films in digital era

Vaishali Khaparde and Ramesh Sutar
Department of Library and Information Science
Dr. Babasaheb Ambedkar Marathwada University
Aurangabad, INDIA
Films Division, Mumbai, INDIA
e-mail: vaishali_khaparde@rediffmail.com; ramesh.sutar@ymail.com

ABSTRACT

In the age of digitization, preservation of film and its restoration has taken on commercial as well as historical importance. This paper deals with the preservation and the digital restoration of films in various formats. Journey of the film material since the nitrate base film to polyester has been discussed with temperature requirements. The issues like journey from Nitrate to Polyester film, attempts made by various institutions in the film preservation, film restoration, rescuing damaged films, digital restoration of film images, temperature required for various kinds of film materials have been explained with the help of tables.

Keywords: Restoration; Preservation; Films; Digital Era.

INTRODUCTION

Film preservation refers to the physical storage of the film in a climate-controlled volt. Repairing and copying the actual film elements are also part of the preservation. In the digital era, film has been taken up commercial value in place of historical importance. Audiences demand the highest quality picture and sound in the digital formats. Meanwhile, the dominance of movies, advertisement in moving images, various cable channels, television broadcasting have proven a source of long term revenue sources. Nowadays there is tremendously increased in the viewership of film media in an extent that nobody has imagined before about the rise of this media. Thus the organisations attached to the film media are very much conscious about the film restoration and preservation of their archives considering the commercial value and strong financial incentives of this media.

Worldwide Attempts made by various Institutions

In 1926, Will Hays asked studios to preserve their films by storing them at 40 degrees at low humidity in an Eastman Kodak process. The British Film Institute was founded on 30th September 1933 with the objectives "to develop the National Film Library to form a comprehensive collection of significant films, to arrange for the loan and exhibition of films from such a library, and generally to revolve facilities for individual and group study of films and the showing of special programs". In 1935, New York's Museum of Modern Art began one of the earliest institutional attempts to collect and preserve motion pictures, obtaining original negatives of the Biograph and Edison companies, and the world's largest collection of D.W. Griffith films. The following year, Henri Langlois founded the

Cinematheque Francaise in Paris, which would become the world's largest international film collection.

Report of the International Federation of Film Archives

This report recommends that the temperature in the store shall be kept as low as possible above actual freezing point. A temperature of not less than 33 degrees Fahrenheit or more than 40 is recommended. When a film is taken out of a vault the process of warming should be permitted to take place gradually over several hours. Films stored should be taken out and examined every five years. If there are signs of deterioration in a positive, a negative should be made from it. It is important that films deposited for storage should never be used for projection. In order to ensure the best possible photographic quality after successive duplication the following must be observed. Firstly, acetate duplicating positive or duplicating negative stock should be used according to whether a positive or negative print is being made. Secondly, the contrast of the image must be kept below that which is customary in prints used for ordinary projection. Finally, very high or very low densities must be avoided in order to secure as nearly linear reproduction as possible.'

Recommendations of the Librarian of Congress in Consultation with National Film Preservation Board

Film preservation is necessary because of film's unstable chemical properties. Most obviously unstable is cellulose nitrate, the support base used in virtually all-theatrical films produced before 1950. Nitrate's dangerous flammability at relatively low temperatures, along with its greater age, long made is the almost exclusive focus for preservation attention. Decisions have become less simple, however, with the growing realization that the cellulose acetate ``safety'' film that replaced nitrate has no greater permanence and degrades at essentially the same speed, if with less fire hazard. Further complicating the problem is the rapid fading of new ``dye-coupler'' colour emulsions that became standard after 1953.

Proper storage conditions delay, but do not stop the decomposition process. Ultimately, the only way to preserve film is to copy into longer lasting material. Polyester-based material is replacing tri-acetate material as the new standard. Polyester is very stable and (unlike nitrate and acetate) it does not shrink. There are no known decomposition stages for polyester.

FILM MATERIAL OF MOVING IMAGES: A BRIEF HISTORY

Motion pictures started in the late 1880s, and many film gauges ranging from 8 mm to 75 mm, were used, but most are now obsolete. Over the last 100 years three main types of film base have been used, cellulose nitrates cellulose acetate and polyester. Cellulose nitrate was introduced in Australia in 1889, and was the main type of 35mm professional film stock used by filmmakers until the early 1950s. Nitrate is highly flammable and from the moment of manufacture, it slowly decomposes, going through various decomposition stages. Decomposition can be slowed down by maintaining controlled storage conditions. We have many nitrate films that are nearly 100 years old that can still be screened on the projector as they have been stored in controlled temperature.

Then there is the cellulose acetate based material, which can be separated into two distinct types, Diacetate and Triacetate. Diacetate based films were used between the 1920s and 1950s. Triacetate replaced both nitrate and diacetate films early in the 1950s, it

was labeled safety, as it is not flammable. Acetate film also decomposes, experiencing `vinegar syndrome'; this can be triggered by several causes, including storage in high temperature/humidity environments. If vinegar syndrome films are left untreated, the film can develop a gray/white crystalline deposit.

Historically, nitrate film is closely associated with the early cinema, and for more than half of a century, it had a part in its development as a growing industry and art form. The cellulose nitrate plastic made motion-picture film possible by providing a strong and transparent flexible support on which a photographic emulsion could be coated. In the late 1880, it became possible to manufacture a sufficient length of photographic film to make possible the analysis and decomposition of movement on a screen, thus inaugurating photographic moving images. In other words, the manufacturing procedure developed in 1889 by the Eastman Company launched a series of technical innovations that led to a changing film technology. This continuing evolution of film has altered not only the way motion-picture films are made but also the way our cinema heritage has been preserved and should be preserved in the future. From the beginning, film archivists have faced a variety of problems associated with film preservation. Dealing with highly flammable nitrate film base, witnessing the decomposition of nitrate, observing the spread of the so-called "vinegar syndrome" in acetate collections, and discovering faded colour prints in their vaults, are all common experiences for archivists.

JOURNEY FROM NITRATE TO POLYESTER FILM

Nitrate Film

Until 1950, nitrate base was used exclusively for 35mm cinematography film for black and white and colour film. Sixteen (16) mm and 75 mm films and magnetic films were made on acetate base. In the manufacture of nitrate base, a cellulose ester is treated with nitric acid to produce cellulose nitrate. Organic plasticizers are added to eliminate brittleness. These nitrogen compounds are very unstable, even under most favorable conditions nitrate film decomposes. It is highly inflammable. In the 1930s, acetate propionate was used to manufacture amateur movie film. It was only in the late 1940s, that a suitable solvent for triacetate became available in commercial quantities and at a competitive price. This was the decisive step towards the industrial production of triacetate, which became an acceptable substitute for the nitrate base being used for professional motion-picture film. The manufacture of nitrate film base was discontinued in the 1950s.

Acetate Film

During the development of safety film, stocks were manufactured with bases of acetate butyrate and acetate -propionate. Most of the safety film is produced with a base of tri-acetate. Acetic acid compounds are much more stable than nitrate compounds. This film is no more inflammable than paper. Since acetate film carries no fire risk and is not dangerous to its surroundings, it is not necessary to take greater fire precautions as compared to nitrate film. This film is no more inflammable than paper.

Polyester Film

In 1955, the introduction of polyester polyethylene terephthalate (PET) marked a major advance in film technology. First used in a number of applications that required high dimensional stability, polyester base not immediately gain favor as a motion-picture film support, partly because it could not be manufactured by solvent casting, as other types of film supports were. All cellulose esters were cast by adding the appropriate solvent and

plasticizers to the polymer. Similar casting machines were used to produce both nitrate and triacetate base. Polyester is insoluble in common solvents, and the film base is formed by melt extrusion.

As a result of the changing technology of film manufacture, motion-picture collections today are composed of films on nitrate, acetate, or polyester base. ``Acetate'' is a generic term that covers diacetate, acetate propionate, acetate butyrate, and triacetate base.

Table 1: Film base used to manufacture motion-picture film.

Film Base	When Introduced	Major Uses
Cellulose nitrate	1889	Film base for professional motion-picture film until the 1950s
Cellulose diacetate	1920s	Used to launch home-movies market.
Cellulose acetate Propionate	1930s	Used for amateur movie film.
Cellulose acetate Butyrate	1930s	Used mostly for sheet film.
Cellulose triacetate	1948	Replaced nitrate film base in the 1950s. Still used for most camera negatives.
Polyester	1955	Increasingly used for motion-picture film since the 1990s (e.g., print films, intermediate films.)

Decay prevention of Nitrate Film

The introduction of cellulose triacetate film base in 1948 marked an important step in the manufacturing of photographic film. The new cellulose triacetate film support provided a slow-burning material, and one considered being more stable than the flammable nitrate base. Triacetate film base is now known to be an inherently unstable plastic, as prone to spontaneous chemical decay as nitrate. However, this long-awaited substitute for nitrate film initiated a strategy based largely on photographic duplication techniques. In theory, any nitrate film could be duplicated onto safety film, resulting in a desirable copy that would limit the risks associated with fire and which would be more stable. This new possibility led to extensive and costly duplication programs conducted in major archives, and, to some extent, it allowed the prioritization of duplication initiatives based on the state of preservation of the originals. Film condition tests were developed to achieve this task. This situation led to an approach that was unique at that time. Duplication onto acetate base is the key to film preservation. In the late 1960s such statements as `nitrate films are unstable and should be eliminated as rapidly as possible,'' and ``since nitrate is inherently unstable, and would eventually have to be copied, effort should be concentrated on a testing and copying program, rather than on full air-conditioning to extract the maximum life out of nitrate copies'' were common place. This indicates that the field had given up on nitrate film and that stringent storage conditions were not perceived as a possible approach to the prevention of further losses. Nitrate films, in some ways, were expected to vanish. In other words, preventing the decay of nitrate films was seen as a lost cause.

CHALLENGES OF TRIACETATE BASE FILM

Nitrate base was a predominant component photographic film for more than fifty years, and properties shaped an enduring idea of what film preservation should be. Until

recently, nitrate represented a dreaded and impossible task for film archivists. It was looked upon as an unwanted material – one to be eradicated from the film archive world. Nitrate films were lost in fires, discarded, destroyed for silver recovery, removed from archives, and allowed to deteriorate due both to their inherent chemical instability and improper storage. However, nitrate films in excellent condition constitute an invaluable portion of a number of collections and demonstrate by their presence that nitrates film base can last for a long time. The nitrate films in archives today are older than most acetate base films. Film stability studies conducted in the 1990 s confirmed the fact that, while the stability of nitrate can vary widely from one film to another, nitrate base film can achieve extended life expectancy. Things have changed since the early 1950, when motion-picture film manufactures stopped using nitrate base and replaced it with cellulose triacetate base. Experience has been gained in collection management, large film stability studies have been conducted, and new techniques have emerged in recent years, which have led to the development of new preservation strategies. In many ways, the nitrate experience brought us to film preservation as it is today Perhaps surprisingly, nitrate film challenges the stability of triacetate base film which was once believed to be a more stable material than nitrate, but which today is known to be a major threat to film collections.

ACETATE FILM BASE: AN INCOMPLETE ANSWER FOR FILM PRESERVATION

Preserving our film heritage does not end with the copying of unstable nitrate films on triacetate film stock. Although this has been the rule of the years, and many archives have spent considerable funds on copying their nitrate film collections, studies have indicated that nitrate and acetate in fact may be similarly unstable. The entertainment industry has produced a tremendous amount of motion picture film on triacetate base stock since the 1950s; and it is only in recent years the polyester base has played a significant role in motion picture film manufacturer. Recent study on stability of film highlights on the proper storage conditions. Air condition with proper temperature can improve the stability of both nitrate and acetate film. Various film stability studies have been conducted by film institutions and archival during last few years. These studies indicated to deal with chemically unstable materials such as photographic film, duplicating nitrate film and providing optimum storage conditions may have been the complete response to prevent further challenges for film archivist.

FACTORS AFFECTING THE CHEMICAL DEGRADATION

Temperature and relative humidity are the main factors that affect film stability. The chemical reactions involved in film base decay and colour dye fading are hydrolytic in nature, which means that they need water as a reactant. Consequently, if more water is available, as it is in high humidity conditions, more chemical changes will be promoted. Heat provides the energy to make the chemical changes happen. Therefore, higher temperatures induce faster chemical changes.

CONTROLLING FURTHER DECAY

The acetate film in any sizeable collection can usually be broken down into four categories (see Table 2). Film in the first category can last several centuries in proper storage. Films in second and third categories can last long enough to be duplicated if kept in adequate

storage. If the damaged films in the forth category are not treated using special duplication or restoration techniques, they will be lost. Table 2 reveals that the proper storage is an effective option for film preservation.

Table 2: Observations of films in different conditions

Film Condition Category	Characteristics	Preservation options
(1) Good and fair	Films are not decaying, or are just starting to decay	Films can last a century at cool temperature and several centuries if kept in cold storage.
(2) Actively decaying	Film may decay at a fast pace depending on storage conditions.	Films can last a century in cold storage
(3) Critical	Films are still usable. However, shrinkage and warping are imminent.	Films can be stabilized in cold storage while awaiting duplication.
(4) Damaged	Films display various degrees of shrinkage and other extreme manifestations of decay.	Current restoration procedures may not be able to save these films. Digital techniques will extend restoration possibilities.

Ignorance about proper storage

The great majority of films made in the silent era have been lost forever. Movies of the first half of the 20th century were filmed on an unstable, highly flammable cellulose nitrate film base, which required careful storage to slow its inevitable process of decomposition over time. Most films made on nitrate stock were not preserved; over the years, their negatives and prints simply crumbled into dust. Many of them were recycled for their silver content, or destroyed in studio or vault fires. However, the largest cause was intentional destruction.

Silent films had little or no commercial value after the silent era ended in 1930. Consequently, silent film preservation has been a high priority among movie historians. Because of the fragility of film stock, proper preservation of film usually involves storing the original negatives and prints in climate-controlled facilities. The vast majority of films were not stored in this manner, which has resulted in the widespread decay of film stocks.

The problem of film decay is not limited to films made on cellulose nitrate. Researchers and specialists have found that colour films are also decaying at a rapid pace. A number of well-known films only exist as copies of original production or exhibition elements because the originals have decomposed beyond use. Cellulose acetate film, which was the initial replacement for nitrate, has been found to suffer from vinegar syndrome. Indeed the preservation of colour films has now been found to involve a compromise, because low temperatures, which inhibit colour fading, increase the effects of vinegar syndrome, while higher (normal room) temperatures cause colour fading.

Film restoration

Film preservation is slightly different from film restoration. Film restoration indicates the act of returning the film to a version most faithful to its initial release to the public and often involves combining various fragments of film elements. It is the process of repairing damaged films, whether in celluloid film or video tape, both by physical and digital restoration process and presenting a new pristine sequence of images in any media.

Film repair

Film can suffer many forms of physical damage. All films need to be carefully examined and repaired to ensure a film can be safely copied or projected. Repairing film requires great attention to detail to repair broken perforations, rips or tears and splices.

Rescuing damaged film

During early stages of decay, the film content can be rescued by transferring it to new film stock. Once the film becomes brittle, it cannot be copied in its entirety. Because the gelatin emulsion usually stays intact during the degradation process, it is possible to save the image on sheet film using solvents to dissolve the emulsion away from the shrunken base. Once the emulsion has been freed from the shrunken support, it can be photographed or transferred to a new support. Because of the solvents used, this is a delicate and potentially hazardous procedure and is an expensive process for a large collection. Degraded motion picture film cannot be restored in this way, but sheet films often can.

DIGITIZATION OF FILMS

The visual information can be transmitted through a combination of new communications and digital technologies, many roles are opening to film archives. However, for all the hopes and promises, their exact future is not at all clear. Many iconic Indian films have been lost forever or are in extremely poor condition.

Digitization would be an ideal way to preserve the contents of cellulose acetate film; current standards do not allow for scanning at sufficient resolutions to produce a copy of the same picture and sound quality as the original. Currently, the National Film Preservation Institute advocates film-to-film transfer as the best method for film preservation and store the copies in proper environmental conditions.

Different Opinions about Digitization of Films

Today it is universally agreed that the foundation of film preservation is proper protection from external forces while in storage with controlled temperature. These measures retard deterioration better than any other methods and it is a cheaper solution than replicating deteriorating films. Some peoples from the archival community feels that conversion from film to a digital image results in a loss of quality that can make it more difficult to create high quality print based upon the digital image. They also feel that the digital video does not match the resolution and depth of film. However, the digital technology pointed out that the resolution in film image and digitally transferred images are equal.

DIGITAL RESTORATION OF FILM IMAGES

Digital restoration is the use of film scanners, to produce an ``electronic intermediate'' and film recorders to duplicate film. Potentially it can handle any format, any process, and almost any deterioration of the image, provided some image is still there, copying with serious image fading. It can disguise scratches and marks and reconstruct, within reason, missing images. Digital restoration can be considered as an image duplicating systems like any other film duplicating sequence. The immediate image stage may be on tape, disc or frame store. The final film is usually a colour negative from which prints can be made by conventional printing.

Digital Film Restoration Technique is the direction of preventing the damage to the negatives and restoring their quality. This technique includes thorough inspection of the film and the status of the negative; analyze the important aspects like image resolution and vibration, granularity, colours and responses, mould, missing frames, grain reduction, scene touch-up, noise and density vibrations. Secondly, the film restoration will be taken up to restore the original quality, effectively dealing with the damaged parts due to fungus and dust deposits. The films so restored will be recorded on either the negative or the DVD or tape format depending upon the requirement of the client or as per the importance of the films.

Examples for Digital Restoration

- Modern restoration techniques for colour film use modern film materials designed to interface with other modern materials and were never designed to duplicate old film images. Few of the current modern film restoration routes resemble the original route. This restoration would provide better, more accurate results.
- Tined and toned nitrate film is currently copied onto modern colour negative film and a modern graded colour print made, or a black and white duplicate negative is made from the original coloured projection print and this printed by various techniques onto modern colour print film.
- Unmasked colour negative film of 1950 is printed onto modern colour print film using black and white separation positives and a modern colour negative film as intermediate stages.
- A set of separation negatives is printed onto black and white film and the resulting positives printed in register using RGB filters onto modern colour intermediate film to make a colour negative. This is printed onto a modern colour print stock. This system is a procedure developed from the commercial protection master method still today.
- Scratches and dust can be removed by various film techniques but ``copied in'' scratches and dust images from earlier generations cannot. Digital restoration can remove or minimize these effects and also ``reconstruct'' missing images, caused by film damage.
- Digital restoration can restore images that are difficult or impossible to restore any other way apart from dye fading and repair of image damage and dirt. This includes:
    i. 1920's to 1950 colour prints on `duplitised' two-colour film.
    ii. Very early tined or toned that have faded in patches irregularly, and faded stenciled and hand coloured films where one dye is the worst. Photographic methods now exist for the restoration of most tined and toned films.

INDIAN SCENARIO

National Film Archives of India (NFAI) and Films Division

NFAI and Film Division are the two institutions working under Ministry of Information and broadcasting, Government of India. Both the institutions preserved very old films in a large scale. Films capture the cultural heritage of a country and present as a form of entertainment. They are vital in showcasing the history, art, culture and lifestyles of many generations. This is clearly reflected in the movies which are being restored to pristine condition. A number of classic films and documentaries produced between 1930's and 1950's have been lost due to the natural conditions and the rest are slowly degrading due

to different factors of the environment like high humidity, moisture, poor storage conditions and neglect. These organisations have been started the restoration, conservation and the preparation of copies for access using current commercial film digitization techniques and the currently available printing and duplicating film stocks. The collection of documentary films of the Films Division has been transferred in to DVD's, VCD's and the digital tapes like DG Betas and High Definitions. The process of digital restoration is still going on.

CONCLUSION

Film archivists are confronted by the problem of aging and degrading film collections. Nitrate and acetate base and colour dyes are the inherently chemically unstable components on which the production of moving images depends. Field experience and stability studies indicate that the loss of our film heritage is not irremediable.

Temperature and relative humidity are the main factors that affect the film stability. Climate control through air-condition is the only way to preserve our film heritage in its original form. However, proper storage conditions delay, but do not stop the decomposition process. However, many film collections may be decaying at an unacceptable rate due to improper storage and a lack of awareness of the extent of the problem around the world.

Ultimately, the restoration of these films in to digital formats likes DVD's DG Beta, DV-CAMS and D5 is the only way to preserve films with the minimum loss of its original contents and quality. Digital Film Restoration Technique is preventing the damage to the negatives and restoring their quality. This restoration may provide better, more accurate results but the question remains about the life of these digitized tapes. It will take time to prove the life span of this digital material may be one generation.

The media storage summary is illustrated in Tables 3 to 6 (Adelstein 1996).

Table 3: Types of Decay that Threaten Media

Type of Decay	Media	Recommended Environment
Silver Image Decay	Photographic glass plates Black and white film Black and white photographic prints	30% to 50% RH
Colour Image Decay	Colour film Colour photographic prints Inkjet prints	Low Temperature 30% to 50% RH
Colour Bleeding	Inkjet prints	30% to 50% RH
Yellowing, Staining	Colour photographic prints Inkjet prints	Low Temperature 30% to 50% RH
Binder Degradation	Magnetic tapes	Low Temperature (not frozen) 30% to 50% RH
Nitrate Decay	Nitrate - base film	Low Temperature 30% to 50% RH
Acetate Decay	Acetate-base black-and-white film Acetate-base colour film	Low Temperature 30% to 50% RH

	Acetate-base magnetic tape	
Glass Deterioration	Photographic glass plates	30% to 50% RH
Layer Separation	Photographic glass plates CDs and DVDs	Minimal temperature and RH fluctuations 30% to 50% RH
Mold	All Media	30% to 50% RH

Table 4: Temperature categories as per ISO standards

30 % to 50 % RH require for all temperature	
ROOM	68 0F (20 0C)
COOL	54 0F (12 0C)
COLD	40 0F (40 0C)
FROZEN	32 0F (0 0C)

Table 5: Environment suitability for storage of various media types

Storage conditions	Nitrate	Acetate		Polyester		Magnetic Tape		CDs / DVDs
		B/W	Colour	B/W	Colour	Acetate	Polyester	
Room	No	No	No	Fair	No	No	No	Fair
Cool	No	No	No	Good	No	Fair	Good	Good
Cold	Good	Good	Good	Very good	Good	Good	Fair	Good
Frozen	Very good	Very good	Very good	Very good	Very good	No	No	Good

Table 6: Qualitative Rating System

No	Likely to cause significant damage
Fair	Does not meet ISO recommendations but may be satisfactory for extended periods
Good	Comparable to ISO recommendations
Very Good	Will provide an extended lifetime.

REFERENCES

Adelstein, Peter Z. 1996. IPI Media Storage, Quick Reference, pp. 1-7