Optimizing Preservation and Presentation of Cellulose Nitrate Film Collections

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Abstract

The sensitivity of cellulose nitrate (CN) films to degradation has been studied and described since the early 1930s. The traditional efforts for preservation of cellulose nitrate film collections for many institutions included establishing of duplication programmes for the most threatened films.

Two fundamental initiatives describing the current situation were initiated at the Danish Film Institute (DFI): Firstly, a systematic survey was conducted in to reveal the chemical and physical signs of decay in the CN film collection. Secondly, analysis of the storage environment using the Climate Notebook software developed by Image Permanence Institute. Combining the results of these two efforts demonstrated that life expectancy varied from 10 years in the actual storage facilities to more than 200 years with improved storage conditions (-5°C, 30% RH).

The presentation will discuss the effects of building good storage environment compared with alternative solutions, including copying and digitisation of the film elements, and destruction of the original nitrate materials. The conclusion is that, even from an economical point of view, building good storage environment for the original cellulose nitrate films is to be preferred to other solutions. On the other hand presentation of digitally restored nitrate film titles also gives new opportunities for film archives to present their films to the public.

Introduction

Original still and motion picture film on cellulose nitrate supports represents valuable historic documents, containing very high image quality both in black-and-white and colour. However, CN film is sensitive to decay. When stored under improper conditions the stability can be very limited in time. Nevertheless, research indicates that it is possible to extend the useful life of still surviving nitrate films to several hundred years when stored in a proper environment.

Cellulose Nitrate

Relatively pure CN was first prepared in 1845. CN was employed in alcohol-ether solution as "collodion" in 1846 and was used by F. Scott Archer for the collodion wet-plates photography in 1851. In 1864 CN was plasticised with camphor for the first time.[1] CN is a polynitrate ester of cellulose. CN is manufactured from dried cotton linters, or paper pulp, steeped in a mixture of concentrated nitric and sulphuric acids to remove water. The concentration of the acid governs the degree of nitration obtainable. The "nitro cotton" is then washed for several days in a large amount of water to ensure that all traces of acid do not at a later stage initiate its decomposition. The degree of substitution of the hydroxyl groups and polymerisation determines the properties and applications of CN.[1] Celluloid has been used for many purposes but is to a large extend substituted by other compounds.

Cellulose Nitrate Photographic Film Base

Since 1887 CN has been used as support for photographic still negatives and from around 1890 as support for motion picture films. During the 1920s and 1930s cellulose nitrate were substituted by different cellulose acetate products, but not until the late 1940s when cellulose triacetate base was introduced for professional motion picture film did CN film become obsolete as a base material. Thus more than fifty years of motion picture film was produced on CN film base, as well as large parts of still photographic collections from the same period.

Decay of Cellulose Nitrate Film Base

The degradation of CN films has been studied and described extensively in the 1930s, 1940s and later in the 1990s.[2-4] First the inflammability of the CN base was of great concern. CN ignites in air at 160°C.[1] In comparison cellulose triacetate ignites at 305°C and spontaneously combusts at 475°C.[5] Eastman Kodak states that self-ignition has taken place at sustained temperatures only slightly above 38°C.[6] Secondly, the more slow chemical decomposition has

been studied. Typical signs of chemical decay in CN are shrinkage, brittleness, acid odour and discolouration of base as well as images.

The Nitrate Collection at the Danish Film Institute

The collection contains around 5000 Danish as well as foreign film titles. Only 25% of the 1300 feature films produced in Denmark between 1903 and 1930 still exist (FILM 33, 2003).[7] However, the collection also contains a large number of documentaries including 70 film titles that formed the First Film Archive from 1913 (The First Film Archive, 2001).[8] The collection is stored on 27.000 reels and is estimated to weight around 70-80 tons.

Storage History of the Nitrate Film Collection

The majority of the CN film collection at the Danish Film Institute was in 1962 placed in an old fortification constructed with an air conditioning system designed to create a climate at 12°C and 50% RH (relative humidity). However, due to typical problems with the building construction of the vaults water was transported from the ground through the walls causing continuing humidification of the vaults which the air conditioning system were unable to control. This resulted in a high relative humidity, which besides rapid chemical decay also caused problems with mould growth in the motion picture films. Analysis of the storage climate made by the Image Permanence Institute using the Climate Notebook Software indicate a predicted lifetime of less than 100 years for fresh films and only 10-15 years of degraded films.[9]

Condition Survey of the Nitrate Film Collection

In 2001 a condition survey of the CN film collection was made. Physical and chemical signs of deterioration were observed on a random sampled part of the collection selected by using a statistic model.[10] The result of the observations (which included shrinkage, base deterioration, brittleness, acidity test etc.) were divided into five categories where 1 is best 5 is most decayed materials. The interpretation of the results is that film in category 1 and 2 are in good conditions and can still be used. Film in category 3 clearly shows signs of decay and will benefit from an improved storage environment. Film in category 4 and 5 will also benefit from better storage but they will need at least restoration treatment before use or special careful if not beyond restoration.

The result of the condition assessment of the CN collection of the Danish Film Institute is that more than half of the nitrate elements show significant signs of decay. However only 8% of the collection is badly degraded (films in category 4 and 5) while 52% of the collection shows some signs of decay. However, the rate of decay can be slowed down significantly if the storage environment is improved to –5°C, 30% RH according to table 2 (see below). Finally, 40% of the collection is in good condition and can survive for many more years if stored in a proper environment.

Table 1. The overall result of the condition assessment survey shows that 40% of the collection is in good condition (category 1 and 2), while 60% of the collection suffers form decay (category 3, 4 and 5).

		Condition Category in %				
	No. of titles	1	2	3	4	5
CN films	5000	5	35	52	7	1

Preservation of the Nitrate Film Collection

It is clear that both the inflammeability and the chemical decay of cellulose nitrate films demand a special storage environment. It is difficult to find a building ground and the construction costs is much higher when compared to the average of construction storage for other archive and museums objects. The National Fire Protection Association in the USA have formulated specifications for building safe and sound storage facilities to CN motion picture and still negative collections (NFPA-40).[11] A design for the 80 tons of CN films meeting the requirements in NFPA-40 and stored at –5°C and 30% RH were developed for the Danish Film Institute. This project stipulates a total of cost of $US 6 million. This corresponds to $US 6.000 per storage m^2 compared to around $US 1.000 per m^2 for climate controlled storage containing museum objects. On top of this, much higher running costs should be added.

The best practice for preserving the CN film is therefore often discussed. However, first it is necessary to examine alternatives to preserving at least the image content of the CN film collections. This issue is discussed below including ways of reducing materials on CN film base.

Analogue Copying to New Photographic Film (Cellulose Acetate or Polyester Film Base)

In the duplication of nitrate film to new (until recently often cellulose acetate 35mm elements) several advances were made in the process during the last Century. Step-printing to increase image stability, the Desmet-color process by which tinted and toned images could be produced from b/w elements, and maybe most significantly wet-gate printing appeared as a commonly used process in the 1980s. These processes have to a certain extent made previous duplication obsolete, thus maintaining necessity of preserving the original as long as it is still possible, since each generation of printers made it possible to create better duplicates from the original.

Moreover, in the late 1980 the vinegar syndrome as relating to cellulose acetate base decay was researched[12] indicating the CN film still extant might outlive the duplicate of the same film on cellulose acetate film.[4]

Digitization

Digitization and the advent of high-resolution scanners and telecine equipment have yet again increased the stakes and potential in motion picture duplication and restoration. However, most digital scanners are not produced to handle archive film. They are produced to fit the needs of film producers and directors, and do so by offering high quality image and effects manipulation capability and superior preview facilities in a business where time is a lot of money.

Some archives and digital facility houses have developed relationships in which the new digital equipment is used to facilitate duplication and restoration of archive materials. The most commonly used digital film equipment in Europe is a Phillips Spirit film telecine with a color correction unit connected to it (DaVinci). The files generated from this process are commonly imported in an Inferno workstation and re-recorded back to film on an Arrilaser film recorder. The dominant resolution is 2K (1920x1440 or 1920x1080) and 10bit over sampling delivered as 8bit (in all three color channels, i.e. in some cases referred to as 32bit).

The digital process is both in financial and quality terms superior to any other process when it comes to correcting color faded film elements. However, there is still an ongoing discussion as to the resolution and bit-depth needed to retain all inherent information or data in a film element. 2K and 8 bit is adequate for display at film quality in a theatrical setting, however, in order to produce a data file containing all data in a form to allow grading after the scan a higher bit-depth and possibly also higher resolution is needed. Most film scanners do not feature a wet-gate and some cannot handle shrunken film, therefore many films are first duplicated onto a new film element using analogue technology and then scanned from this new element. Therefore a digitization is not a strictly digital process, but a transfer from analogue to digital, which features many 'analogue' problems such as the quality of the transferred element and its physical transport through the capture gate (line array or fixed array).[13]

Storage on Other Media than Film

Currently there is no digital format for film that is trusted to keep data for more than 5-10 years. The amount of data space required by even a small archive (i.e. maybe 1000 titles) makes a server solution unimaginable. Therefore a tape or digital photographic data film (still only a prototype) are the only alternatives to bringing film back to analogue film for long term preservation.

Deaccession or Destruction

Destruction of highly degraded CN film beyond restoration or without readable image information is necessary because the self-ignition temperature in such film is quite low. Plans for deaccession or destruction film elements on CN film base after transferring the image content to a new support or digitised is discussed occasionally. The idea behind is that building and maintaining expensive storage facilities for fragile and inflammable cellulose nitrate film bases can be avoided. Many archives have experience with loss of quality or information during copying. Moreover the UNESCO's Recommendation for the Protection of Moveable Cultural Property covers "archives, including […] photographs, cinematographic films, sound recordings and machine-readable records".[14] Section 19 states that "Member States should, where the situation calls for it, take the necessary measures to: (a) provide for sanctions or any appropriate measures, whether under the penal or civil code or administrative or other measures in the case of […] damage intentionally caused to such property".

Repatriation

Film Archives typical include both national and foreign film titles. Often lost film titles are discovered in other film archives. For examples several Danish film titles were found in Norway, Sweden, The Nederland's and Russia. Sometime it is suggested that Film Archives could send foreign film titles to the country where the film title originally was produced, thus only concentrate on preserving the national film heritage. However, often the film was released in a version specifically intended for the public in the specific country or language area, and can therefore be claimed as part of than country's national film history or culture. Furthermore, it is believed that in general the total amount of film to be preserved in a national film archive is not reduced if all foreign film titles were send to where it originally were produced.

Archival Storage of CN Film

The inherent stability of CN film base materials varies to a great extent. This makes lifetime predictions difficult. However, based on experimental data from research in CN degradation IPI predicts a 500 years lifetime when storing at 10°C, 50% RH for films without acid degradation. For CN film with signs of decay it is recommended that the storage temperature should be below 0°C according to table 2.

Table 2. Storage recommendation for CN films is given in table 2 according to IPI and ISO.[15]

	Temperature, °C	% Relative Humidity (RH)
IPI: CN film with good appearance	-10	20-50
	2	20-30
IPI: CN film with possible degradation	-5	20-30
	-16	20-50
ISO 10356:1996 for CN film	2	20-30

Preservation of Nitrates vs. Copying/Digitization

Every process available in film duplication offers shortcomings of one sort or another, this is no different in

digital film transfer. Some of handling problems in digital transfer equipment can be minimized by first producing an optimum analogue duplicate, however, all analogue processes entail loss of original information. In television, resolution (SD, 720x572) has not been altered since the 1970's, never-the-less videomasters produced on old telecine scanners are today considered inferior to transfers at the same resolution made on current equipment. Who is to say that the same will not happen to high definition film transfer? If the original nitrate film is retained, every new development in transfer equipment, analogue or digital, offers the potential of performing a better and more precise rendition of the original. The question is therefore less what to preserve, but rather when to duplicate, and to which quality and cost. Digitization in this light becomes predominantly an option for films needed for access, and less a pure preservation/back-up duplication, since that will merely add to the number of elements to preserve and handle.

Access to the CN Film Collections

Access to the original nitrates is too most not possible in projection. Only a handful of archives have the facilities to run nitrate films and the situation is comparable to fragile drawings only having a limited lumen capacity left. Access is therefore limited to duplicates on modern 35mm film or in video formats. Focus has always been on the feature films to be restored to 35mm, whereas documentary footage typically comes to life in new documentary production predominantly meant for television broadcast.

The DVD medium has brought a renewed interest among the public for classic films. Silent cinema, for a long time a forgotten art, has become more generally available than ever and archives are considering exploitation and presentations of their collection on DVD. DFI has commenced a series of ten DVDs containing classic works of the first thirty years of Danish cinema. The Internet may hold new potential for special interest and orphan materials, as these are made accessible and searchable, often in low-resolution (mpeg1, quicktime, etc.).

Strategy for Preservation and Presentation of the CN Film Collection at the Danish Film Institute

Based on the recent knowledge on degradation, storage environment and copying/digitisation and the result of the condition assessment of the collection, the Danish Film Institute has decided on a strategy where new storage facilities are built for preservation of the original CN film elements and presentation of the image content of selected feature and documentary films on the DVD medium.

A new construction based on the NFPA 40 standard recommendation has been proposed with the costs of US$ 6 million based on an environment set-up at –5°C, 30% RH with yearly running costs expected around US$ 150 for each film element.

For comparison the costs of digitising for a 2K solution of the Danish film productions on CN bases has been calculated to around US$ 35 million for digitisation only. The intellectual work on identification and retrieving the films followed by preparing the film elements for digitisation is calculated to around US$ 100 million.

Conclusion

Based on the current knowledge on chemical and physical stability and degradation of cellulose nitrate film base combined with the experience from more than 50 years of duplicating, copying, transferring to tape and latest digitisation the conclusion is that:

Original film elements on CN base are expected to last for many hundred years under optimum storage condition. Even the useful life of degrading film can be extended for many years in a cold and dry storage environment.

Transferring to another carrier has during the last 50 years proved to be an inadequate solution for preservation. On the other hand digital processes hold the potential of lowering the cost and generational loss in restorations and reconstructions. Moreover presentations using DVDs or other digital media can reach a large audience and make the presentations more informative by including additional materials on the films and maybe the thinking behind the restoration.

It should be kept in mind that heritage institutions should be ensuring authenticity in presentation and the long term preservation of cultural artefacts.

It can be concluded that the cost of keeping the original film materials in a good storage environment at the moment is much lower than keeping digital media in an optimal and readable format.

The final recommendation is that original CN film elements should be kept under optimum storage conditions (e.g. at -5°C, 30% RH) while restoration, reconstruction and presentation can be done using a digital media remembering always documenting the link from the original to the digital copy.

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Biographies

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