From condition assessment survey to a new preservation strategy for the Danish Film Archive

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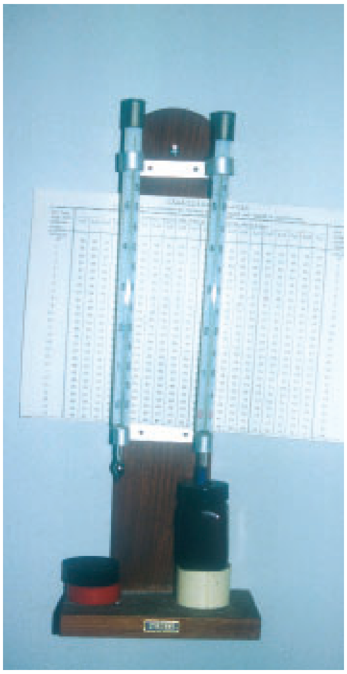
The effort to improve the life expectancy of the motion picture collection at the Danish Film Archive is based on two fundamental initiatives to describe the current situation: firstly a systematic deconstruction of the physical, chemical and biological signs of decay in the collection (see Bonde Johansen and Braae, 2002) and secondly an analysis of current environmental conditions. A description of how the condition of the films and their storage climate will interact and influence the possibility of preserving the film collection is given by Bigourdan and Santoro (2001). Based on this knowledge predictions for future preservation priorities in a given storage environment can be drawn up. Moreover, it is possible to compare different storage environments both in terms of what will be lost and in terms of the most cost efficient solution where costs of duplication/digitalisation can be weighed against cost of storage.



Based on the quality of the future storage environment for the film collection it will also be possible to focus on the consequences for preservation of individual film titles in terms of duplication and restoration priorities: in other words, to describe a preservation plan including the type of film materials and even identifying the film titles that should be prioritised for restoration work.

We conclude by demonstrating that a good storage environment for the film collection is the most (cost) efficient way to preserve the film heritage in every way.

STORAGE HISTORY OF THE FILM COLLECTION

Before 1952 there is no information as to where the collections were stored. From 1952 to 1962 the films were placed in former barracks with no safety precautions or climate control. In 1962 an abandoned fortification known as “Bagsværd Fort” (Photo) was converted for film storage with a number of smaller vaults for cellulose nitrate (CN) and cellulose acetate (CA) base films (See Bigourdan, 2002, Figure 1). The fortification was originally built in 1893 as a part of the defence line around Copenhagen. However, the fortification has not been used as such since the end of the First World War.

According to the original working manual from 1962 the air conditioning system at Bagsværd Fort is designed to maintain a temperature of 12°C and 50% RH in the film storage vaults. In 1966 the number of vaults converted to climatized storage rooms was expanded and an extra air conditioning system installed. Until December 1999 there has been no continuous registration or data logging of the climate in the vaults but it has been possible to read the temperature and relative humidity using the dry and wet bulb thermometers installed in each vaults.

From correspondence between the contractor and the Film Archive from November 1967 to October 1968 it is evident that the specified climate was never obtained although many improvements to the buildings were made. The contractor mentions that moisture from outside might be able to penetrate through the plaster and bricks causing constant high relative humidity in the vaults.

In the last correspondence dated October 15, 1968 from the Film Archive to the contractors Board of Directors it is concluded that the air conditioning system is not at all capable of meeting the specification agreed upon in the contract.

It is believed that from the expansion of the climatized storage area in 1966 until climate measurement commenced in 1999 the climate was as described in Bigourdan (2002, Table 1 and Figures 2 and 3). Moreover, because of increasing lack of climatized storage space the unclimatized corridor was filled with films as was a new 200 m^2 building from 1970.

The storage environment and the condition of the film collection as described in Bonde Johansen and Braae (2002) is therefore primarily the result of the last 40 years of storage history for the film collection at the Danish Film Archive. This is the challenge which a new strategic preservation programme will have to face.

DUPLICATION OR IMPROVEMENT OF THE STORAGE CLIMATE

Previous preservation efforts at the Danish Film Archive and for many film archives in general have involved establishing a duplication programme for the most threatened and/or important film titles. Many film archives have been through an impressive duplication programme of transferring nitrate base film to safety films on cellulose acetate base in order to save the content of the film titles on a less inflammable support. In the late 1980 the vinegar syndrome as relating to the degradation of acetate film base was researched (e.g. Adelstein et. al. 1992-95). This knowledge combined with results from new research on the stability of nitrate film base indicate that the nitrate film still extant might even survive the duplicate of the same film title on cellulose acetate film (See Figure 1 in Adelstein, 2002).

By correlating the results of the condition survey of the film collection with the analytical tools developed by Image Permanence Institute (IPI) (Reilly, 1993 and Reilly et. al., 1995) it is possible to compare traditional preservation strategy based on duplication with the effect on the life expectancy in an improved storage climate.

The condition for this comparison is the current laboratory duplication price in Denmark (2002-level) for the different type of materials.[1] The work needed to prepare the material for duplication is not included in the comparison. The model for predicting the life expectancy for fresh and decaying cellulose acetate films developed by IPI has then been used to calculate the residual number of years where the films can be used as intended in different storage climates (Reilly 1993).

In Table 1 the overall result of the condition assessment survey divided into the five different condition categories is shown (see Bonde Johansen and Braae, 2002). The interpretation of these results is that films in category 1 and 2 are in good conditions and described as "fresh films". The films in category 3 clearly show signs of decay (Photo?). As can be seen in this table nearly 50% of the collections are in condition category 3 except for the preservation materials. Although films in category 3 clearly show signs of decay they can still be used for screening and duplication. However, a bad storage environment will soon increase degradation, which will move the films to condition category 4 or 5. On the other hand improved storage environment will cause a distinct decrease in the rate of decay, which films in category 3 will benefit from most significantly. This will again reduce the need for duplication and restoration, or in other words extend the expensive need for duplication over a longer period of time. Films in category 4 and 5 will also benefit from an improved storage environment but this alone will not solve the preservation problems. Restoration treatment is needed to make it possible to use the material if it is not already beyond restoration (Photo).

Collection	Base	No. of titles	1	2	3	4	5	Total
NM Collection	CN	940	9	36	40	14	1	100
DFI Collection	CN	4000	4	35	55	5	1	100
Shorts & Documentaries	CA	3900	10	49	40	1	0	100
Preservation materials	CA	6564	28	66	6	0	0	100
Prints for screening	CA	15000	5	54	39	2	0	100

Table 1. Collections and results of condition assessment survey.

In Table 2 the results of the condition assessment survey have been recalculated into the number of film titles which still can be assumed to be fresh (Table 2A) and the number of film titles demonstrating signs of decay (Table 2B). The duplication costs are then calculated for fresh (Table 2A) and decaying films (Table 2B) separated into the different materials and the price is estimated. Duplication of the whole collection can then be estimated at around DKK 2 billion. This number can also be described as the economical value of the collection in 2002-prices.

Collection	Total no. of titles	No. of titles in condition category 1 & 2 (%)	No. of titles in condition category 1 & 2	Duplication Avg. price per title (DKK)	Duplication costs (mio. DKK)
National Museum	940	45	423	50000	21
Archive collection	4000	39	1560	50000	78
Shorts & Documentaries	3900	59	2301	15000	35
Preservation masters	6564	94	6164	150000	925
Prints for screening	15000	59	8850	50000	443
Total costs in million DKK					1502

Table 2A. Fresh films.

Collection	Total no. of titles	No. of titles in condition category 3,4 & 5 (%)	No. of titles in condition category 3,4 & 5	Duplication Avg. price per title (DKK)	Duplication costs (mio. DKK)
National Museum	940	55	517	50000	26
Archive collection	4000	61	2440	50000	122
Shorts & Documentaries	3900	41	1600	15000	24
Preservation materials	6564	6	400	150000	60
Prints for screening	15000	41	6150	50000	307
Total costs in DKK million					539

Table 2B. Decaying films.

In Table 3 the expected life time of fresh and decaying films in Bagsværd Fort (Bigourdan, 2002) and in other storage environments (Reilly, 1993) is listed. The storage climate in Bagsværd Fort will only ensure the decaying part of the film collection a useful life of another 10 years. For fresh films the residual life expectancy is 70 years in Bagsværd Fort.

In order to save the content of the film collection a duplication programme could be established. Based on the assumption that the fresh collection needs to be copied within a time span of 70 years the yearly costs will be DKK 21 million each year (See Table 4). In the same way the duplication needs for the decaying portion will cost DKK 54 million each year in 10 years. The annual budget requirement over the next 10 years will be DKK 75 million.

	Storage conditions		
Life Expectancy	Bagsværd Fort (10°C, 80 % RH)	5°C, 30 % RH	-5°C, 30% RH
Fresh film	70	500	2000
Decaying Film	10	200	500

Table 3: Life expectancy for fresh and decaying films under different storage conditions.

Plans for the new storage strategy at the Danish Film Archive include storing the as yet fresh part of the acetate base film collection at 5°C, 30% RH. As indicated in Table 4 this will reduce the duplication costs for fresh films from 21 million DKK each year to 3 million DKK compared to the existing climate in Bagsværd Fort. The decaying portion of the acetate film collection and all the nitrate films is planned for storage at -5°C and 30% RH which will expand the life expectancy from 10 years to 500 years, again reducing duplication needs from DKK 54 million to DKK 1 million a year. If the storage climate is improved as indicated above the yearly budget requirements for duplication will be DKK 4 million.

Climate	**Bagsværd Fort 10°C, 80% RH**	**New archive[2] 5°C/-5°C, 30% RH**
Life expectancy, fresh films (yr.)	70	500
Life expectancy, decaying films (yr.)	10	500
Duplication costs, fresh films (DKK million.)	21	3
Duplication costs, decaying films (DKK million.)	54	1
Total duplication costs each year (DKK million.)	75	4

Table 4. Life expectancy and duplication costs for different storage environments.

Material (storage climate)	Power consumption, new storage[3]
Nitrate (-5°C, 30% RH)	770.000 kW/yr.
Preservation materials[4] (+5°C/-5°C, 30% RH)[5]	400.000 kW/yr.
Prints for screening (+5°C, 30% RH)	87.400 kW/yr.
Total power consumption	1.257.400 kW/yr.
Total number of film titles in the collection in 2002	31.000
Power consumption/film title	41 kW/yr.
Passive preservation costs/film title/year.[6]	62.00 DKK

Table 5: Power consumption and passive preservation costs/year.

In Table 5 the estimated costs for storing the film collection in terms of power consumption are given. The calculation ends with costs of DKK 62 per film title each year (2002 level) for a storage climate corresponding to a life expectancy of at least 200 years for the decaying films (see Table 3). The total costs for keeping the film title will then be DKK 12400 per film (2002 level) for the next 200 years. The comparable laboratory price for producing a preservation master of a colour feature film is DKK 150000 (see note 1).

Moreover, the actual storage capacity of the facilities mentioned above is at least 40.000 film titles, which means that more films can be put into the storage without increasing the expected power consumption. It should be noted that the price for renting the storage is not included. Furthermore, the estimated power consumption is based on the average outdoor climate in Denmark. This may vary depending on the local climate. Local costs of making duplicates may also vary from place to place. However, even with a double or triple increase in power consumption and less expensive duplication costs there is still a very large difference between the passive preservation costs of a film title and the cost of duplication material, not to mention the total costs of a complete restoration.

THE CELLULOSE NITRATE DILEMMA

The first 50 years of cinema, film was made on cellulose nitrate, which constitutes a major preservation challenge. Preserving the original nitrate based film materials requires a cold and dry storage climate in order to slow down the rate of chemical decay and to obey safety measures stipulated by the fire brigade due to the high inflameability of the material. Today in the digital age (and indeed earlier) the possibility of separating the content of the motion picture from the nitrate base itself and transferring the content to a more stable medium has continuously been considered.

For several reasons the ultimate preservation goal of a film archive must be to preserve (and preferably to present) the film titles in the media originally produced. Combining experience from storing nitrate film materials with the recent research results on stability indicate that the surviving nitrate materials could still be around for many more years if stored correctly.

Based on the results of the condition and environmental survey at the Danish Film

Archive the preservation perspective of the nitrate collection is more than 200 years if stored at -5°C and 30% RH.

Based on this recommendation a draft for a purpose-built archive for the nearly 5000 film titles in the nitrate collection has been proposed. The project describes an archive which will meet the NFPA-40 standard.[7] The total cost is estimated at DKK 47 million. An alternative to this solution would be to migrate the content of the nitrate film materials to another medium and dispose of the nitrate films themselves. Today, scanning followed by the transfer of the images to a digital storage medium is the preferred solution.

75% of our nitrate films are of Danish origin or of national interest for documenting Danish film production and Danish film culture. The collection corresponds to a total of more than 7 million meters of film. Today's price for scanning this collection is estimated at DKK 200 million. The cost of preparation work and materials should be added to this figure, and is estimated to be at least twice the scanning costs. Furthermore, the estimated costs of maintaining the digital stored data seem surprising high.[8]

The conclusion for the cellulose nitrate film collection at the Danish Film Archive is that even from an financial point of view preserving the original nitrate films in a good storage climate is to be preferred to copying and digitisation. The cost of building a new archive is very high but far from the expenditure required by preparation and digitisation followed by the destruction of the original nitrate film materials.

PRESERVATION PLAN

Storage strategy

From the results of the condition survey (see Bonde Johansen and Braae, 2002) the storage climate analysis (see Bigourdan, 2002) and the relevant ISO-standards (ISO 18911, 10356, 18911, 18923) on recommended storage climates, the Danish Film Archive has decided on the strategic preservation plan for storing the collection indicated in Figure 1.

At the time of writing (September 2002) the Danish Film Archive has established a cold storage room at 5°C, 35% RH for the print collection. In January 2002 new climatized areas extending the storage facilities will be completed. These facilities will include preservation masters and shorts and documentaries at 5°C and 30% RH. Storage facilities for magnetic tapes and videos will be managed at 8°C, which is the lowest temperature recommended by the ISO-standard (ISO 18923) and 35% RH. Special storage facilities for acetate films attacked by the vinegar syndrome at -5°C, 30% RH will also be available. Finally, the draft for establishing a new storage for the nitrate collection at -5°C, 30% RH has been proposed as mentioned above.

In Figure 1 the expected lifetime of new and properly processed materials is indicated by the diagonal lines at different combinations of temperature and humidity according to IPI (Reiley, 1993). This is true if the new materials are stored constantly in the same climate. When using the film materials the expected lifetime is reduced according to

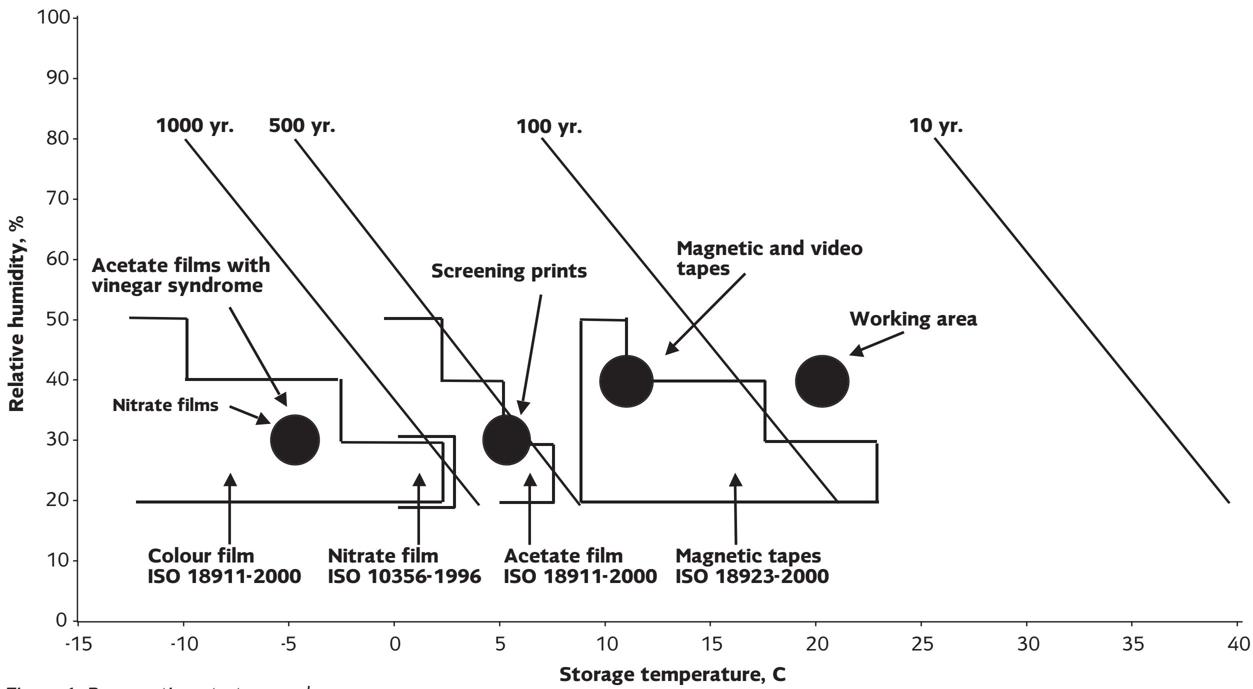


Figure 1. Preservation strategy and storage climate at the Danish Film Archive.

the climate difference and the time out of storage. For example at 5°C and 30% RH the life expectancy is 18 times longer than at 20°C and 50% RH. However, if the film is outside the 5°C/30% RH-climate 30 days each year the expected lifetime is only 8 times better than at 20°C and 50% RH (McCormick-Goodhart). If the expected life-time is 450 years at 5°C and 30% this will be reduced to 250 years if the film is outside the cold and dry climate 30 days each year.[9]

Continual chemical decay to degrading films will also reduce the expected lifetime compared to fresh materials. Results from research indicate that at 21°C, 50% RH the life-expectancy for fresh materials is 40 years while it is only 5 years in the same climate when the film has reached the auto catalytic point of the degradation process. As indicated in Figure 1 a storage climate of -5°C and 30% RH is suggested for cellulose acetate films with vinegar syndrome and for nitrate films. The life expectancy of these already decaying materials is therefore not more than 1000 years, as might be indicated in the figure, but may only be around 200 years.

Restoration strategy

The other major result of the condition assessment survey is more precise knowledge of the actual stability problems in the film collection. This makes it possible to isolate specific stability problems calling for restoration efforts, or alternatively reveals areas where the condition of the film is surprisingly good. For example, only 6% of the preservation masters show signs of moderate degradation while 94% of these materials are in good condition.

On the other hand one of the surprising results of the condition assessment is that there is a correlation between the development of the vinegar syndrome and the bleaching of colours in colour films produced before 1976. From the point of view of cinema history priority has been given to collecting and preserving materials produced by Danish documentalist filmmakers. Jørgen Roos, Jon Bang Carlsen and Jørgen Leth are among the important ones, and of the three only Jørgen Roos and Jørgen Leth produced colour films before 1976. Based on this knowledge priority will be given to restoring and duplicating colour films produced before 1976 by Roos and Leth.

A number of specific preservation problems came to light during the condition assessment survey and those issues is now described in the preservation programme for the Film Archive.

CONCLUSIONS

By improving the storage environment the rate of decay will be reduced, which will in turn reduce the need for duplication/digitisation significantly. More precisely, it will be possible to divide the costs of duplication and restoration over a larger number of years. Instead of fighting acute stability problems by making second or third generation duplicates of perhaps less important film titles, the improved storage climate will make it possible to add more value to the film collection. This means combining work on preserving the original material with intellectual work on the film titles, on identification, history and content and finally the restoration and presentation of the collection to researchers and the general public.

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NOTES

1. Average costs for duplication of a Cellulose nitrate film is DKK 50 000 DKK per title, Shorts & Documentaries: DKK 15 000 per title, Preservation materials (colour, feature films): DKK 150 000 per title and screening prints (colour, feature films): DKK 50 000 per title.
2. Fresh film will be stored at +5o°C, 30% RH. Decaying films with vinegar syndrome and all nitrate films at -5o°C, 30% RH.
3. For nitrate and preservation masters the power consumption is estimated, the consumption for screening prints is actual number each year.
4. Including feature film, short and documentary films
5. Fresh film: +5o°C, 30% RH, Decaying films with vinegar syndrome: -5o°C, 30% RH.
6. The price of 1 kW electricity in Denmark is DKK. 1.50 (2002-level).
7. NFPA 40 Standard for the Storage and Handling of Cellulose Nitrate Film 2001 Edition.
8. A conservative estimate is 50% of the original scanning costs (RGL DigiNews, 1999)
9. This calculation is only valid for chemical stability (bleaching of colours and base stability) and does not reflect wear and tear due to handling of the film material.

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RESTORATION