# New long-term storage facilities at the Royal Library, Denmark: storage requirements for mixed collections

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*Abstract*

This paper describes the course of the planning phase for the building project of a new storage at The Royal Library in Denmark. It illustrate the pitfalls and dilemmas conservators and building engineers have to navigate within, when seeking to balance the preservation goals against the economic costs of a building project. Standards and recommendations were used to set requirements for environmental conditions and to find compromises for mixed collections. To address preservation issues knowledge of the different materials in the collections and their preservation state must be combined with knowledge on the impact of environmental conditions on the longevity. The building project succeeded in establishing high quality storage for unstable materials with a cold storage for photographic collections at and a cool storage for books.

*Résumé*

Cet article décrit le déroulement de la phase de planification du projet de construction d'un nouvel entrepôt à la Libraire Royale au Danemark. Il illustre les pièges et dilemmes auxquels sont confrontés les conservateurs-restaurateurs et les ingénieurs en construction, quand ils cherchent un équilibre entre les objectifs de préservation et les coûts économiques du projet de construction. Normes et recommandations ont été appliquées pour définir les conditions environnementales requises et pour trouver des compromis dans le cas des collections mixtes. Pour résoudre les questions de préservation, il faut combiner la connaissance des différents matériaux composant les collections et de leurs conditions de conservation avec la connaissance de l'impact des conditions environnementales sur leur longévité. Ce projet a réussi à établir un entrepôt de grande qualité pour les matériaux instables avec un magasin froid pour les collections photographiques et un magasin frais pour les livres.

*Synopsis*

Este artículo describe la fase de planificación del proyecto de construcción de un nuevo depósito en la Biblioteca Real de Dinamarca. Ilustramos aquí las dificultades y dilemas con los que tienen que lidiar

## Introduction

The Royal Library in Denmark houses around 143 running shelf kilometres of collections of national importance in closed stacks. Throughout the history of the library lack of space has been a recurring issue, which the many different storage buildings indicate: the collections are kept at nine different addresses around the city of Copenhagen. Some of the stacks are built for storage of library collections, other are just industrial buildings. Even though the environment plays a key role in the effort to ensure long-term preservation, it is not possible to control the environment sufficiently in most of the facilities.

The materials found in the collections are: bound books, illuminated parchment manuscripts, paper manuscripts, palm leaves, textile rolls, globes, photographic prints and negatives, graphic art and maps. A survey based on random sampling, of the state of preservation of the collections (Bevaringsplan 2010) showed that a large proportion of the collections consisted of unstable organic materials such as acidic paper and photographic negatives with acetate or nitrate base.

Apart from the nitrate negatives, which have been segregated from the negative collections because of the potential fire hazard, the library's principle is to keep the collections together in themes. This means that materials with different stability levels are stored next to each other. One typical example is that hand made rag paper, which has been around for several hundred years, is mixed with acidic wood pulp paper, which can become so brittle that it disintegrates in less than 100 years.

In mixed collections the varying levels of stability means that different materials, or assemblies of materials, can have different and sometimes contradictory requirements for an ideal storage environment. Therefore, specifying the environment is often a complex compromise between different preservation needs. Another problem is that some materials, especially the unstable cellulose based materials, emit harmful gasses that contribute to the overall deterioration of the collections.

This article describes the process of specifying compromises for environmental set points and implementation of the requirements in the building project.

los conservadores e ingenieros cuando deben sopesar los objetivos de preservación y los costos de un proyecto de construcción. Se emplearon estándares y recomendaciones para establecer los requisitos de las condiciones ambientales y encontrar compromisos para el caso de colecciones mixtas. Así, se debió combinar conocimientos de los distintos materiales en las colecciones y su estado de preservación con los conocimientos del impacto de las condiciones medioambientales sobre la longevidad de dichos materiales para establecer su adecuada preservación El proyecto de construcción prosperó en establecer espacios de depósito de alta calidad para materiales inestables con ambientes fríos para las colecciones fotográficas y ambientes frescos para los libros.

## Premises for the building project and its organisation

The building project started in 2004 with the aim of adding a second building to an already existing storage building (block 1) which houses 30 shelf kilometres of books and photographic materials. The project had a fixed appropriation from The Ministry of Culture and the library was mandated to build a minimum of 25 shelf kilometres of storage capacity and 3000 $m^2$ reading rooms and to furnish all facilities (Figure 1). The building should be ready for use by 2008 (Figure 2).

The Board of the Royal Library decided to use the same architects (Dissing & Weitling) as used when block 1 was built. This should ensure a harmonic architecture and their knowledge of the existing facilities was expected to minimise the technical challenges of unifying the two buildings. The architects decided to use the same engineers (Ramboll) as used in block 1.

The building organisation was led by a Steering Committee headed by the library and with the architect and engineers group as members. The Technical Building Group was an internal library group, consisting of Preservation, Building Service, Security, Logistics, Storage Management, Faculty Library as well as Administration. The group worked as advisor on all major decisions taken by the Steering Committee. Thus the organisation of the building project was complex and involved a range of professionals such as architects, engineers, interior designers, legal advisors, officials, managers, administrators and librarians, all having different interests and priorities.

The library's commission was to design and build a book storage and a cold storage for unstable photographic materials. The Steering Committee presumed the high use book collections should be stored under the same conditions as in block 1, which are 18 ºC/45% RH. Cold storage for the book collections was not considered, because it was expected to delay fast delivery of books to the reading rooms, which has a high priority for the

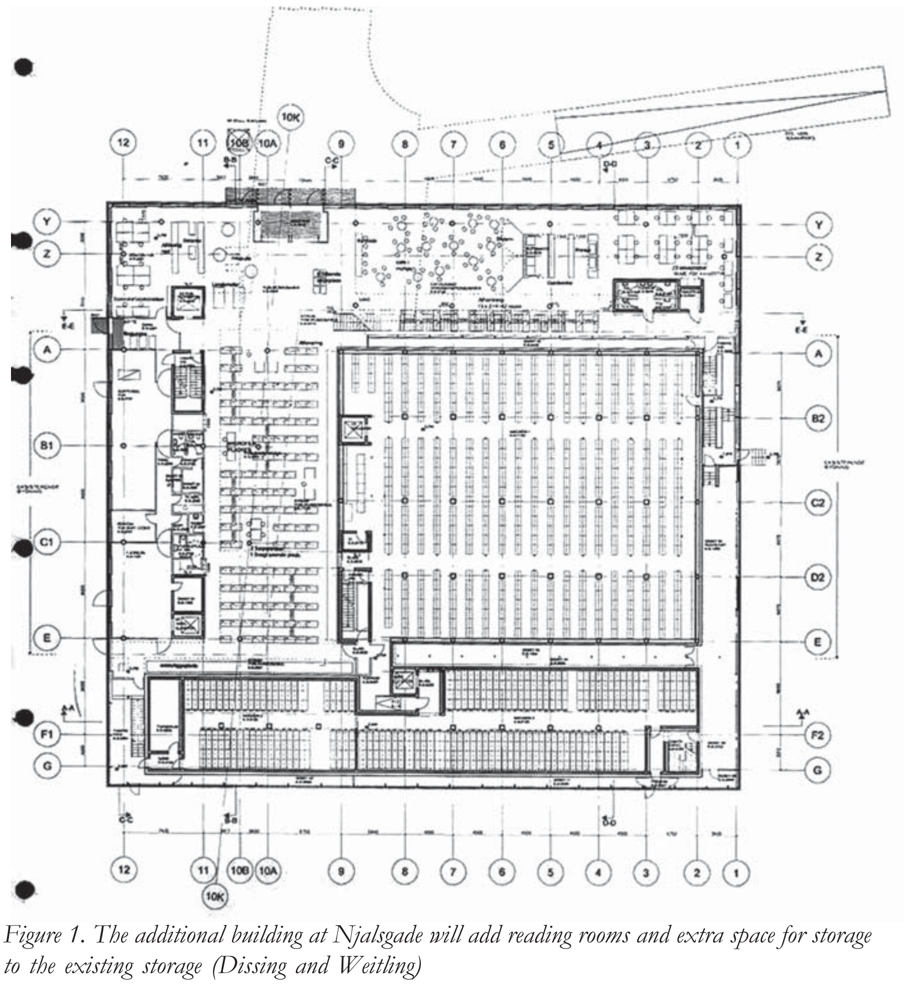

*Figure 1. The additional building at Njalsgade will add reading rooms and extra space for storage to the existing storage (Dissing and Weitling)*

*Figure 2. A computer animated presentation of the new building with reading rooms and storage (Dissing and Weitling)*

library. Since photographic collections generally have a low user frequency, changes in the expedition routines were accepted.

## Setting up requirements for long-term storage

To present requirements for environmental conditions for the Technical Building Group the Preservation Department consulted standards and recommendations for storage environment. The international standard for long-term storage of archive and library materials, ISO 11799 (2003) recommends a series of temperature and relative humidity (RH) requirements for different materials types in the Appendix. The requirements show the difficulties in specifying one set point for mixed collections: For optimum preservation of paper it should be stored at 30–45% RH ±3%, whereas leather and parchment require 50–60% RH ±3%.

The problem with mixed collections is addressed in the photographic standard, ISO 18934 (draft 2004) on storage environment for multiple media archives. This standard sets up four climate zones: room (16–23 °C), cool (8–16 °C), cold (0–8 °C) and frost (–20–0 °C) with a RH between 30–50% ±5% and indicates, again with four levels, how well these zones are suited for storing different types of photographic materials: from not acceptable to best. Inspired by this methodology we designed an extended form, including other library materials (Table 1). We used it to analyse different compromises for setting the temperature in the book storage.

The tool 'Preservation Calculator' developed by Image Permanence Institute was used to compare different climate scenarios and their impact on estimated longevity, the so-called Preservation Index (PI) (2007). This model was developed to predict expected lifetime for acetate negatives, but it can also be used for other unstable organic materials, such as acid paper. The effect on PI of lowering temperature (Table 2) and relative humidity (Table 3) was analysed and used for specifying the needed climate requirements.

Since protection of the large amount of acidic paper in the book collections was a main preservation issue, the compromise in relation to delivery times was to recommend cool storage at 12 ºC and 45% RH. Lowering the temperature from 18 °C to 12 °C results in more than doubling the lifetime, decreasing the aging rate from moderate to slow. A decrease of RH from 45% to 30% prolongs the longevity with approximately 1.5 times, but the low set point was regarded as unacceptably dry for the leather bindings.

Requirement for the photographic collections was suggested to follow international standard ISO 11799 (2003) giving a cold and dry storage with a set point of 2 ºC and 30% RH.

Another problem with ISO 11799 (2003) was that the acceptable pollution limits for air quality seemed too high for some air pollutants compared to recent research (Tétreault 2003), which are also included in the recommendations in the ASHRAE Handbook (2003). The recommendations are based on pollution dose (concentration x time) and present levels where deterioration can be avoided up to 10 years or 100 years, the latest being lower than levels found in most of the other standards we consulted, including BS5454 (2000) and NBSIR (1983). We argued that a national library's preservation perspective should be longer than 100 years and recommended the lowest levels for air quality. For sulphur dioxide, nitrogen oxide, ozone and particles we used ASHRAE (2003) and for acetic acid and formaldehyde we used ISO 11799 (2003).

## Implementing the storage requirements

The climate control in block 1 was ensured via a traditional ventilation unit with particle filtration, heating, and humidifying for the recycled air stream, and with cooling and carbon filtration only in the fresh air intake. The ventilation system is designed with a constant amount of fresh air of approx.

*Table 1. An evaluation of library material's preservation when stored in each of the climate zones*

| Materials (30–50% RF) | | | Temperature zones | | | |
|---|---|---|---|---|---|---|
| | | | Warm (16–23 °C) | Cool (8–16 °C) | Cold (0–8 °C) | Frost (–20–0 °C) |
| Books/ documents | Rag paper | | Ok | Good | Good | Optimum |
| | Wood pulp paper | | No | Good | Good | Optimum |
| | Parchment | | Ok | Good | Good | No |
| | Leather | | Ok | Good | Good | No |
| | Barch, palm leaves | | Ok | Good | Good | No |
| Globes | Metal | | Ok | Good | Good | No |
| | Wood | | Ok | Good | Good | No |
| Photographic materials | Glass plates | | Ok | Good | Good | No |
| | Nitrate film | | No | No | Good | Optimum |
| | Acetate film/microfilm | B&W | No | No | Good | Optimum |
| | | Colour | No | No | Good | Optimum |
| | Polyester film/microfilm | B&W | Ok | Good | Good | Optimum |
| | | Colour | No | No | Good | Optimum |
| | Positives | Unika, POP | Ok | Good | Good | No |
| | | B&W | Ok | Good | Good | Optimum |
| | | Colour, chrom. | No | No | Good | Optimum |
| | | Ink jet | Ok | Ok | Good | Optimum |
| AV materials | Records | | Ok | Good | Ok | No |
| | Magnetic tapes | Acetate | No | Ok | Good | No |
| | | Polyester | No | Good | Ok | No |
| | Optical discs (CD/DVD) | | Ok | Good | Good | No |

*Table 2. Preservation Index at a number of different temperature set points and a relative humidity set point of 45%*

| Temperature (°C) | Relative humidity (%) | Preservation Index (years) | Rate of natural ageing |
|---|---|---|---|
| 22 | 45 | 39 | Moderate |
| 18 | 45 | 64 | Moderate |
| 12 | 45 | 140 | Slow |
| 8 | 45 | 239 | Very slow |
| 5 | 45 | 360 | Very slow |
| 2 | 45 | 548 | Very slow |

*Table 3. Preservation Index at a number of different relative humidity levels and a temperature set point of 12 °C*

| Temperature (°C) | Relative humidity (%) | Preservation Index (years) | Rate of natural ageing |
|---|---|---|---|
| 12 | 50 | 121 | Slow |
| 12 | 45 | 140 | Slow |
| 12 | 40 | 161 | Slow |
| 12 | 35 | 187 | Slow |
| 12 | 30 | 216 | Slow |

*Figure 3. The building site with the original façade of block 1 and the additional constructions to support the new façade. (The Royal Library)*

10% of the total amount of ventilated air. This system has shown several weaknesses. If the internal humidity or the temperature in the storage becomes too high, it is difficult to return to the set points, because there is no cooling capacity or dehumidifying equipment for the recycled air. Furthermore, the recycled air does not pass the carbon filtration unit, and thus internally generated gasses are not absorbed. While designing the new storages (block 2), it was clear, that the concept for climate control used in block 1 could not match either the old or the new requirements for the climate in the storages.

The traditional requirements for temperature and RH allow rather small fluctuations from a stable set point. This tradition has been challenged by the principle of passive climate control, which allows a slow shift in the climate during the year. Within the last few years there has been a growing interest in passive climate control, because of the potential cost savings due to lower energy consumption, and today it is used in several storages in Northern Europe (Christoffersen 1995, Knudsen and Rasmussen 2005, Padfield and Larsen 2005).

Early in the design process, it seemed interesting to build the new storage for books as a passive climate controlled storage. This design is best carried out where the storage can be built into stable surroundings as for example a cellar. However, it is more expensive to establish a cellar, and regardless of savings in operation it was not an option within the existing budget, because the demand for space in form of reading rooms as well as storages had a higher priority. Instead the Technical Building Group suggested that the storage was build with semi-passive climate control, operating where possible with the principles used in passive climatisation, but additionally controlled by a mechanical system to ensure the appropriate climate (Figure 3).

Two models for regulating the climate were considered. In the semi passive model the set points for temperature and RH are allowed to float during the year, approximating the outdoor temperature. The lowest set points in winter are 8 ºC and 40% RH and the highest in summer are 16 ºC and 50% RH (Figure 4). The second and traditional model operates with fixed set points of 12 °C and 45% RH throughout the year. PI was calculated for each of the models and showed that the semi-passive model would increase the longevity with around 25% (Table 4).

The idea of semi-passive climate controlled storages was not easy to get through the consulting group who designed the building. A delicate problem was that the consultants also designed block 1 and problems with the climate control in block 1 had led to a dispute to be settled by arbitration. Consequently the consultants were reluctant to 'experimental' systems regarding block 2,

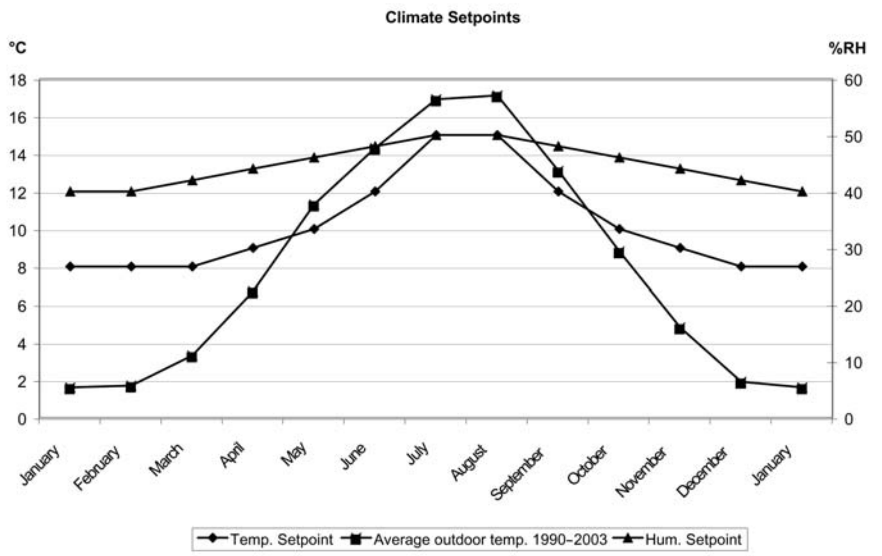


*Figure 4. Climate curve with floating set points for temperature and RH approximating the outdoor temperature*

and suggested to build the climate control in the traditional way. At the same time, the library did not want to push a passive climate control system through, as an unwished side effect of this could be that responsibility for eventually upcoming problems could be unclear. In the end the Steering Committee decided to choose the semi-passive solution, because calculations had shown that it would result in operating costs 1/3 lower than a fixed set point.

*Table 4. Preservation Index for the floating set points compared to a fixed set point at 12 °C and 45% RH*

| Month | Temperature (°C) | Humidity (%RH) | Preservation Index (PI) |
|---|---|---|---|
| January | 8 | 40 | 277 |
| February | 8 | 40 | 277 |
| March | 8 | 42 | 261 |
| April | 9 | 44 | 215 |
| May | 10 | 46 | 177 |
| June | 12 | 48 | 128 |
| July | 16 | 50 | 72 |
| August | 16 | 50 | 72 |
| September | 12 | 48 | 128 |
| October | 10 | 46 | 177 |
| November | 9 | 44 | 215 |
| December | 8 | 42 | 261 |
| Floating set point | 8–16 | 40–50 | 188 |
| Fixed set point | 12 | 45 | 140 |

In block 2 all kinds of filtration and necessary condition of the air is done in the recycled air stream. Controlling the temperature by adding cold fresh air, namely at night, was considered, but it was too expensive to establish, even though it would have led to a decrease in operational costs.

The suggested levels for air quality were heavily criticised because we did not have consistency in the choice of references but choose the lowest levels possible. Another problem was that available analytical technology at that time could not detect the low levels, and thus made a control of fulfilment impossible. The ability of being able to check the contractor was a major requirement for the library, and therefore it could not be accepted as requirements within the building project. Despite the lack of a thorough evaluation of analytical techniques it was decided to use detection limits specified by a analytical report made by external consultants as requirements: Sulphur dioxide 0.02 $\mu g/m^3$, nitrogen oxide 2 $\mu g/m^3$, ozone 1 $\mu g/m^3$, acetic acid 50 $\mu g/m^3$, formaldehyde 0.6 $\mu g/m^3$ and particles 0.1 $\mu g/m^3$.

## Conclusion

The storage building project at The Royal Library has shown that in order to secure highest possible preservation quality within the overall budget, it is important that preservation issues are put forward at the very beginning of the project. To address preservation issues knowledge of the different materials in the collections and their preservation state must be combined with knowledge on the impact of environmental conditions on the longevity (PI). The PI proved to be a very effective way of presenting and arguing for climate specifications in the decision-making process.

Standards and recommendations were used to argue for environmental requirements. Since it is much easier to put forward requirements based on standards, than based on research and recommendations, there is a strong need for standards for mixed collections. Current standards for archive and library materials do not address the problems of contradictory requirements related to mixed collections. Therefore, it was necessary to bring in a methodology used for storing multiple photographic materials, and adapt it to library materials in general.

Good co-operation between the Preservation Department, who proposed the environmental requirements, and the Building Service, who analysed the technical and economic consequences of implementing the requirements, proved useful in the decision-making process, where the architecture and the building economy had high priority.

In conclusion the building project succeeded in establishing high quality storage for unstable materials, with a cold storage for photographic collections at 2 °C ± 1° and 30% RH ± 5%; and a cool book storage with floating set points around 12 °C ± 1° and 45% RH ± 5% and with carbon filtration of air pollutants. The project was less successful in bringing operating costs for the storage into focus, and this could be a threat for the long-term preservation of the collections at the Royal Library.

## Acknowledgements

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