Buildings for Storing Cultural Heritage Objects

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Principles and Methods for Assessing Indoor Environments

NATIONAL
HERITAGE
INSTITUTE

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Edited by Zdeněk Vácha
Opponents: Jan Josef, Miroslav Černý
Translation: Lenka Zimková

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CONTENT

Introduction

We are presenting a publication to accompany and develop some of the topics that could not be addressed in more detail in the *Methodology for preserving cultural objects*, which was the main outcome of the project. The Methodology, through its rules and patterns, does not allow certain topics to be further developed (there are many of them, in view of the project's focus) or excessive subdivision of the baseline. The project's main focus, which includes a wide range of views on issues related to preserving cultural objects in memory institutions, allows thematic expansion in many directions and areas that are often separate scientific fields today; whether they are exact sciences, humanities, natural science, or domains of practical technical activities and specializations of applied fields.

The aim of this publication is to introduce in more detail the principles, methods, and starting points for assessing the indoor environment in buildings containing cultural objects. In dedicated chapters, it addresses the issues concerning a selection of buildings for these purposes, the possibilities to modify them, especially with respect to historical buildings possessing significant monumental value, as well as the fundamentals of planning new buildings, whether for exhibition or archival purposes. It expands the subject of hazards and mechanisms of damage to objects and possible solutions at the same time based on sustainable principles, including modern methods of control and regulation. It also includes investigations of the history of technical equipment and facilities for presenting and storing artefacts, as well as an insight into the past in terms of materials and construction.

The shared foundation of all these texts is extensive experience in the field of museum work, monument care, restoration and conservation, climatology, design of buildings for cultural objects, management, and a wide range of practical activities involved with installations, exhibitions, and depositories.

This book complements the topics included in the Case Studies Database and the Methodology by making available to the public the comprehensive results of partial experiments and methods of examining the indoor environment of objects under this project.

Authors

On the Issue of the Development of Opinions Concerning the Placement of Buildings, with an Emphasis on Buildings Designed for the Presentation and Storage of Cultural Objects, their Orientation, Structural Elements, Materials, Equipment, and Arrangement.

Historical review and summary of the current situation

ZDENĚK VÁCHA

Location of buildings and their orientation

Human dwellings and structures have throughout history generally always been shaped by the natural environment and their anticipated function. In the past and to some extent even today, structures designed to protect people and their possessions have especially conformed to natural factors. To make living conditions acceptable, extreme geographic and landscape locations remained generally unoccupied, and the methods of construction in other areas more suitable for permanent settlement were adapted to the local conditions. To locate the buildings according to their purpose, elements of the landscape and their specific properties (e.g., mountains and their slopes, plains, rivers, and wildlife) were taken advantage of. Other factors were the proximity to roads and water, mineral, and wood resources (heating, construction materials), agriculture possibilities, and making a living in general. For fortified structures, it was the strategic location that particularly played a major role.

A structure's placement in the landscape in relation to altitude, landscape relief, predominant wind direction, windward or leeward side of a slope, insolation, precipitation, etc. were crucial for the necessary structural and physical features of buildings. However, a different situation existed for detached structures or built-up areas (a cluster of buildings),[1] a structure on a hill or in a valley, a structure near running water (river, stream), or near standing water (pond, lake – once again depending on the windward or leeward side). Urban construction regulation was needed to guarantee order and respect for the rights of burghers.

The orientation of buildings has corresponded to these circumstances. However, exceptions in the past have been known, for example, the radial type of medieval settlement of a village forming a circle around a square, which gave

1 Urban construction regulation was necessary for towns to guarantee order and respect for rights. An example is the oldest preserved urban regulation for Czech lands (published for the town of Jihlava by Přemysl Otakar II in 1270), which reads: "So that houses, whoever built them, that could be judged as unfavourable or to the detriment of the city, were completely demolished, and that no houses would be built in the future without the advice and consent of the burghers mentioned above." Citation from NOVOTNÁ, Dana. *Urban Construction Regulations. Critical edition of the building code sources with commentary and application examples.* Brno: National Monument Institute, Regional Technical Office in Brno 2011, p. 26. ISBN 978-80-86752-92-1.

rise to both more convenient and less convenient positions in terms of orientation. Another aspect must have therefore been crucial. The same is true of the medieval location of towns with regular squares as an organizing space, and also churches, which were usually oriented and resigned from the possibility of reacting to local geographic circumstances by changing orientation. If significant deviations existed, they had other causes.

The oldest considerations of the placement and orientation of buildings are known from Roman antiquity. Vitruvius († approx. 25 BCE) observes in his Ten books on architecture[2] to both establishing towns (I. IV. *Selecting healthy places when setting up cities*), and the individual buildings. *In the north, buildings need to be set up… facing the warm cardinal directions. Conversely, the southern regions with much sunshine are exposed to heavy heat and so must be more open and facing the north and northeast.*[3] He also addresses the proper orientation of individual rooms towards the cardinal points (VI. IV *Suitable cardinal directions for individual rooms*), for example, libraries should face east. *Books will not be decayed in such libraries.*[4] *Paintings… and painting studios* are to be oriented to the north for the stability of lighting;[5] the northern side of a building *is not subject to any changes…*[6]

At the same time, Vitruvius deals with technical measures – drainage of soil humidity,[7] wastewater pipes for drainage, etc.;[8] if the walls are damp, he suggests constructing *a second thin wall.*[9]

In his extensive theoretical paper on architecture *Werk von der Architektur* (around 1675) Prince Karl Eusebius of Liechtenstein, an avid designer himself (Château Plumlov), also deals with approaches to construction.[10]

In his opinion, palaces should contain separate summer and winter flats; the winter rooms are to be oriented towards the south and facing the courtyard,

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2 VITRUVIUS. 1953. *Ten books on architecture.* Prague: State Publishing House of Literature, Music and Art.

3 *Ibid.*, p. 131.

4 *Ibid.*, p. 140.

5 *Ibid.*, p. 140.

6 *Ibid.*, p. 25.

7 *Ibid.*, p. 118.

8 *Ibid.*, p. 136.

9 *Ibid.*, p. 158.

10 FLEISCHER, Victor: *Fürst Karl Eusebius von Liechtenstein als Bauherr und Kunstsammler (1611–1684). Des Fürsten Karl Eusebius von Liechtenstein Werk von der Architektur*. Vienna and Leipzig 1910.

the summer rooms then outwards and to the north (gegen Septentrio) to be airy and cooler.[11] At the same time, when characterizing the buildings in his property, he criticizes the chateau in Bučovice which was allegedly the best and most beautiful building in Moravia. Arcade corridors (i.e., open arcade communications in the courtyard) are in his opinion useless both in summer and in winter, as they are burdened by rain in the summer and snow in winter.

> *… All the shortcomings cannot be attributed to the builder, our ancestor from mother's side, Mr. Jan Šembera, but to that idiot, the builder who ordered it, and who was responsible for understanding everything correctly, advising and managing beautiful and perfect work and for guiding the builders on the right path.*[12]

In principle, this is a condemnation of the Italian building type of arcade chateaux, then a fashionable renaissance import to our countries, which is inappropriate for the Central European climate near the Alps. It is understandable, therefore, that during the Baroque times and then in the 19th and 20th centuries (to this day), for practical reasons, the arcades were sealed off with bricklaying (for example Uherčice Chateau) or were often glazed (e.g., Náměšť nad Oslavou chateau).

In the seventeenth century, virtually at the same time, specialized booklets appeared dealing exclusively with optimizing the environment for collections. In 1674, Johann Daniel Major gives instructions on the appropriate form of rooms to accommodate the collections and directly answer the questions related to their parameters, including orientation. They should be resistant to

mice, rats, cats, nesting swallows, robbers, wind, dust, torrential rain, and fire. They should be fitted with windows (but not too many) and be bright with healthy, clean and dry air, facing mainly the southeast, or at least southwest, in no case facing the north.[13]

Similarly, Caspar Friedrich Neickel (1727), the founder of museography (the science of how to establish museums) and author of a well-known tractate of the same name Museographie (*Museographia oder Anleitung zum rechten Begriff und nützlicher Anlegung der Museorum oder Raritäten- Kammern, darinnen gehandelt*

11 *Ibid.*, p. 110.

12 *Ibid.*, p. 186.

13 GRIESSER-STERMSCHEG, Martina. *Tabu Depot. Das Museumsdepot in Geschichte und Gegenwart*. Wien Köln Weimar: Böhlau Verlag 2013, p. 32. ISBN-3-205-78894-2

wird I. Von denen Museis, Schatz-Kunst- und Raritäten-Kammern insgemein: II. Dem nachmals ein Anhang beygefüget ist, von vielen, welche vor Alters in der Welt berühmt gewesen : III. Im 3. Theile wird von Bibliothequen insgemein… gehandelt: IV. Der 4… Theil… ist eine Anmerckung… von Raritäten-Kammern oder Museis insgemein), which discusses lazy air in the case of southeast orientation.[14]

The theme of illumination (shading) has been common in cases of regulating new buildings ("light service") since the Middle Ages, which is understandable due to the densely built-up areas and the character of the Central European land division in cities.[15]

Due to the generally limited possibilities of provision of food and energy resources for the population in our latitudes until modern times, all available possibilities had to be used owing to the variability of orientation of buildings towards the world's cardinal points, the prevailing winds, etc. The warming of buildings in summer led, even in our conditions, to the need for protection against the sun. However, the arcades of Renaissance chateaux already mentioned are outlandish in our conditions and, as also mentioned, have not proved successful. We can see arcade or column-type porticos and porches of the same purpose in the folk buildings of the southern regions of the former Czechoslovakia.[16]

In winter, it was necessary to maximize consumption of solar energy while minimizing losses due to winds, humid environments, etc. To simplify that, the orientation towards the world's cardinal points can be characterized as follows:

NORTH – no sun, cold, even lighting (associated with
the direction of unpleasant winds and rains).

EAST – sunny in the morning, pleasant in the summer, cool in the winter.

14 *Ibid.*, p. 32.

15 *He who constructs a building and would overshadow the neighbouring buildings, to which the "light service" will not come; this is not the subject of a lawsuit; for no wrongdoing is done by him who exercises his/her rights. Item. There is only an instruction in the Code "not to harm the light", which is a general word meaning every light, whether it be now, or at the time of the contract or a future building, which has not been built yet, the "light service" and other may be administered.* Books on Urban Rights (IUS MUNICIPALE PRAGENSE) Brikcí from Liczka – 1536. Chapter thirty-nine. About the light in the house and rooms with windows. Citation from NOVOTNÁ, *Urban Construction Regulations*, p. 42.

16 MENCL, Václav. 1980. *Lidová architektura v Československu*. Prague: Academia.

SOUTH – high filling with sunlight in winter, little in summer (the sun is high).
WEST – high filling with sunlight in the evening, western façade warmer than eastern (summer associated with undesired warmth) associated with unfavourable direction of wind and rain.

The actual location of a structure designed for the long-term preservation of cultural objects is intended to minimize the risks posed by natural and anthropogenic influences.[17]

In the case of vegetation, both positive and negative effects are seen. Positive effects by using tall vegetation, for example, include shading on the sunlit side or protecting on the windward side. Shrubs, flower beds, and grass areas capture solar energy, and compared to tiled and threshing floors, mitigate excessive loads more effectively. The negative effects of vegetation manifest as damage to facades and roofing from overgrown vegetation that has been neglected, or due to a lack of educational or safety measures, or fallen leaves that have not been removed, etc. Damage to structures by root balls spreading to the foundations or subsoil of the structure is not unusual. They cause statics defects and often damage waterproofing with subsequent moistening of the structure.

The importance of the location of buildings has always been topical, even with far greater technical possibilities available to both historical buildings designed to store cultural objects and new buildings. Placement of a structure is generally the most important factor for the external influences on the (micro) climate of the buildings. It is necessary to consider (apart from the parameters already mentioned), for example, the height of the building itself or the depth of the groundwater.[18]

17 Ing. Milena Forejtníková et al. Methodology for assessing potential threats to monuments by anthropogenic and natural influences, Brno, June 2015, published in reduced form as: FOREJTNÍKOVÁ, Milena, ROZKOŠNÝ, Miloš, DZURÁKOVÁ, Miriam, KONVIT, Igor, PAVLÍK, František, OŠLEJŠKOVÁ, Jana, and MLEJNKOVÁ, Hana. Methods of assessing threats to monumental objects by selected natural and anthropogenic influences. In: *Reports of the National Monument Care institute 2014, year 74*, a. 5, pp. 373–378. ISSN 1210-5538.

18 ANGERMANN, Thilo. Kulturschutz durch Klimastabilisierung im Depot. Ein Plädoyer für Anwendung der Temperierung. In: Edd. STÄBLER, Wolfgang and WIEßMANN, Alexander. *Gut aufgehoben. Museumsdepots planen und betreiben.* Berlin München: Deutscher Kunstverlag, 2014, pp. 79–80. ISBN 978-3-422-07296-1.

Structural elements and materials

The range of constructions and building materials, partly based on the original Mediterranean (ancient) roots, has been stable under our conditions for centuries, but changed around the middle of the 19th century with the first structural use of iron (cast iron, steel) and concrete based on Portland cement.

In today's sense, the term *concrete* was introduced by a Frenchman, Bernard Forest de Bélidor (1697–1761), in his book *Architecture hydraulique*. This material and the term associated with it spread in the nineteenth century.[19]

Until then, the most accessible building material was wood. Later, it was stone for more demanding constructions (ecclesiastical and fortified buildings, municipal buildings, and some residential town houses), in the form of broken rock and quarry / block brickwork (chopped blocks), of which the latter was rather rare in Czech lands.[20] Later, more brick (including moulded bricks) and other building ceramics were used from the mid-13th century,[21] often in the

19 SPRINGER, Veronika. *Beton (Concrete) Material und Oberflächengestaltung im 1. Drittel des 20. Jahrhunderts am Beispiel Münchner Bauten* [online]. München: Technologische Universität, 2005 [cit. 3. 3. 2017]. Retrieved from: http://www.rkk.ar.tum.de/fileadmin/w00ble/www/media_rkk/downloads/Beton.pdf.

20 ŠKABRADA, Jiří. *Konstrukce historických staveb* (*Constructions of historic buildings*). Prague: Czech Technical University, Faculty of Architecture, 2000, p. 7. ISBN 80-01-02071-1.

21 SLIVKA, M. (1980) Tehla ako stavebný materiál (Brick as building material). Paper on the history of brickwork. *Pamiatky a príroda: metodicko-odborný a informačný bulletin* (Sights and the countryside: Methodological and professional bulletin), *5, 26–28.* Bratislava: Obzor.
HOLUB, P., KOLAŘÍK, V., MERTA, D., PEŠKA, M. (2011) Středověká brněnská architektura z cihel (Brno Medieval architecture from bricks). In: *Dějiny staveb: sborník příspěvků z konference Dějiny staveb 2010* (History of Buildings: Conference Proceedings from the History of Buildings conference 2010). Pilsner: August Sedláček Club, pp. 139–159. ISBN 978-80-87170-17-5
NAGY, Peter. (2011). Stredoveké tehly na Slovensku (Medieval bricks in Slovakia). In: *Laterãrius. Dejiny tehliarstva na Slovensku* (History of brickwork in Slovakia). *Zborník Slovenského národného múzea* (Proceedings of the Slovak National Museum). *Archeológia Supplementum 3.* Bratislava: Slovak National Museum – Archaeological Museum, pp. 31–43.
LÍBAL, Dobroslav. (2003). Problém kontinuity stavebně-keramického materiálu v raném a vrcholném středověku (The issue of the continuity of ceramic building materials in the Early and High Middle Ages). *Zprávy památkové péče (reports for the Journal of Historical Heritage Preservation institute).* Prague: Jalna, 2003, 2, pp. 83–84. ISSN 1210-5538.
FLODROVÁ, Milena. Brno brickwork plant called *"Na leči"* in the 14th to 16th centuries. In: BARTÁK, Martin, ed. *Archeologia technica 10: examination of production facilities and technologies by archaeological methods: Proceedings of seminars held in 1994 and 1995*. Brno: Technical Museum in Brno, 1996, pp. 110–113. ISBN 80-901880-3-6.

form of so-called mixed masonry (a combination of stone and brick). Timber was always used as a building material for parts of structures (trusses, ceilings, etc.). It also served to insulate otherwise brick structures in the living quarters in castle and urban architecture already since the High Middle Ages (insertion of timbered structures). Masonry residential buildings of the Middle Ages were mostly massive. However, besides the classic method of bricklaying, lightweight frame and half-timbered constructions appeared both as the dividing partitions of interiors and outer walls. In the Renaissance, the technology of thin-walled plastered structures appeared and bricks dominated. However, bricks were only most widespread in the 19th century, when they dominated rural construction.[22]

The 19th century saw a completely revolutionary wave of the use of iron (cast iron, steel, etc.) as a structural element (for example the Greenhouse in Lednice, built in 1843–45 according to the Georg Wingelmüller project, which is based on the original solution from 1838–40 by English architect Peter Hubert Desvignes)[23] in combination with glass. At the turn of the twentieth century, *eternit*, the asbestos and cement template, appeared as a new type of incombustible roofing. Ludwig Hatschek started producing asbestos plywood and gaskets in Schöndorf in Upper Austria. From 1900, he added Portland cement to the mixture to obtain solid slabs, and under the trade name Eternit he obtained Austrian Patent No. 5970 for his product.[24]

Metal skeleton constructions were then gradually employed, not only in industrial constructions (in residential buildings, probably first time in the world and in our country at Villa Tugendhat 1928–29, Ludwig Mies van der Roheworld), and at the same time concrete (reinforced concrete) constructions,[25] whose prominent examples include the Commercial Industrial Palace (Pavilion A) at the Brno Exhibition Center from 1927–28 (project by Josef Kalous and Jaroslav Valenta).

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22 ŠKABRADA, Jiří. *Konstrukce historických staveb (Construction of historical buildings)*, pp. 9–10.

23 FABIÁNOVÁ, Bohdana, ed. *Lednice na Moravě, Chateau palm house: papers presented at an international seminar held on 17–19 June 2002 marking the completion of historical restoration*. Brno: State Monument Care institute in Brno, 2002, pp. 20–41. ISBN 80-85032-90-2.

24 BRÜCKLER, Theodor. *Thronfolger Franz Ferdinand als Denkmalpfleger. Die "Kunstakten" der Militärkanzlei im Österreichischen Staatsarchiv (Kriegsarchiv).* Böhlau Verlag: 2009, p. 59. ISBN 978-3-205-78306-0.

25 SPRINGER, Veronika. *Beton (Concrete) Material und Oberflächengestaltung.* Retrieved from: http://www.rkk.ar.tum.de/fileadmin/w00ble/www/media_rkk/downloads/Beton.pdf.

The issue of fire protection concerning special buildings was of prime interest and arose in the 19^{th} century, concerned with the preservation of collections of cultural objects. This was related to losses caused by fire such as the Court Library in Vienna in 1848, which contained museum collections, the fire of the Vienna Theatre Ringtheater in 1881, which then generally led to stricter fire protection measures in public buildings[26] (the fire of the National Theatre in Prague broke out in the same year). The Imperial Court movables warehouse (Hofmobiliendepot, 1900–1901) was built as a steel skeleton for fire protection reasons. Similarly, the main archive on the Minorite Square in Vienna was also designed and built at that time.[27] These buildings include fire compartments, and there were already fire hydrants on each floor at the Austrian Museum of Art and Industry in Vienna (1907–9).[28]

While the manner of constructing buildings were traditional until the Baroque period, since the 19th century the range of materials and technologies has expanded, opening new design possibilities. These include the materials mentioned above, such as Portland cement, structural iron (steel) and cast iron, large-scale glass use, eternite, bitumen as an insulation material, etc. Gas and then electric lighting was introduced, heating and mechanical ventilation systems become parts of buildings, as well as electrically powered lifts, etc. Purlin systems were promoted for carpentry systems and wooden roof trusses were also replaced with steel.

However, the building and physical properties of more demanding structures with a wide range of materials and complex technical solutions were more often at the limit of extreme demands on operation, maintenance, and overall sustainability. This is why modern depository buildings today are mainly built as "heavy" or "passive", an example being the most recently opened depository building of The Prussian Palaces and Gardens Foundation in Potsdam with walls almost one meter thick, the depository being mostly tempered by its building mass.[29]

For the basic characteristics of the structural and physical properties of historical residential buildings and former residences in castles and chateaux

26 GRIESSER-STERMSCHEG, Martina. *Tabu Depot. Das Museumsdepot in Geschichte und Gegenwart*, p. 56.

27 *Ibid.*, p. 56.

28 *Ibid.*, p. 57.

29 STRIMMER, Ute. Zwei neue Zentren für preußische Geschichte. *Restauro 5/2017*, p. 29. ISSN 0933-4017.

(serving today, for example, as monuments accessible to the public), the heating system is extremely important, as other important construction elements are connected to it. Flue gas installations still have a major influence on the behaviour of historical buildings from the point of view of the indoor environment. According to Jiří Škabrada's typology, the basic division of heating devices is into *direct / indirect* and *smoking / semi-smoking*. Indirect heating especially, with stoking from adjacent spaces was typical in our countries from the Middle Ages until the 19th century, that is, similar to archaic direct heating connected to chimney funnels, which were gradually replaced with modern chimneys in the mid-19th century. Hot-air heating systems appeared in the first half of the 19th century.[30] In 1823, a Viennese named Paul Traugott Meissner published a paper on heating with heated air (*Die Heizung mit erwärmter Luft*). At the same time, generous ventilation systems (in the first phase still separate from heaters) that anticipated air conditioning started to be applied, especially in municipal buildings such as parliaments, concert halls, theatres, museums, hospitals, and schools of the "Gründer Age".[31] In 1865, Ferdinand Artmann[32] published a study on public building ventilation issues. He distinguished "natural ventilation" and ventilation supported by thermal or mechanical ventilation. In 1865, the concept of *central heating* (Centralheizung) was established. In 1885, a manual for heating and ventilation technology (Lehrbuch der Heiz- und Lüftungstechnik) was published by Friedrich Paul with 770 pages. *In the middle of the 19th century, all the essential issues were quantifiable, controlled, hygienically necessary, and user-friendly, i.e., per person, air exchange known and standing at the centre of consideration about house technology at the time.*[33]

30 ŠKABRADA, Jiří. *Konstrukce historických staveb* (*Construction of historic buildings).* Ed. 1. Prague: Argo, 2003, pp. 257–285. ISBN 80-7203-548-7.

31 HUBER, Alfons. Ökosystem Museum. Grundlagen zu einem konservatorischen Betriebskonzept für die Neue Burg in Wien [online]. Wien, 2011, p. 33, [cit. 3. 3. 2017]. Dissertation. Akademie der bildenden Künste Wien. Institut für Konservierung-Restaurierung. Retrieved from http://www.khm.at/fileadmin/_migrated/downloads/diss_120105.pdf

32 ARTMANN, Ferdinand. Kritische Betrachtungen über den dermaligen Standpunkt der Ventilations-Frage. In: *Zeitschrift des österr. Ingenieurs- und Architektenvereins*, VI–VII. Heft, 3-86, Wien, p. 120–148. ISSN 0372-9605. pp. 120–148.

33 HUBER, Alfons. Ökosystem Museum, pp. 38–43. Retrieved from http://www.khm.at/fileadmin/_migrated/downloads/diss_120105.pdf

These technical advances were used extensively in the construction of new museums, galleries, and similar public buildings whose technical infrastructure itself can now be the subject of monument protection.

Ensuring the stability of the environment through natural means (passive air conditioning, as mentioned above) is achieved by a number of historically proven methods comprising the construction parameters of structures and their ventilation, heating, drying, and other systems, which we have written information about from antiquity (see Vitruvius, above). Historical examples were summarized by Manfred Koller,[34] who dealt with a wide range of issues associated with preventive conservation. As early as in Baroque period, for example, a sophisticated method for protecting paintings on false altars (especially in recesses) against cold, moisture, and biological threat existed in the form of "boxes" – with charcoal and an additional air gap of approximately 20 cm.[35]

Dislocation of space by function

The nineteenth century is considered a "century of museums", which is related to their increased numbers and especially to the creation of specialized buildings for collection institutions.

The first conceptual proposals for museum space deployments date back to the 1990 s, when William Henry Flower, Director of the *Natural History Museum in London*, divided museum space into exhibitions open to the public (*public exhibitions*) and depositories (*reserve collections*). In his ideal scheme, he proposes a solution where both sections occupy the same area, the difference mainly being in the manner of lighting.[36] Further progress in the planning of specialized museums comes with the German Alfred Lichtwark, who, as an architect,

34 KOLLER, Manfred. Zur Geschichte der vorbeugenden Konservierung. In: *Restauratorenblätter*, Bd. 15, Wien: Schutz und Pflege von Kunst- und Baudenkmälern, 1995, pp. 27–38. ISSN 1017-6373.

35 KOLLER, Manfred and VIGL, Michael. Die Seitenaltäre von Maria Kirchental: Untersuchung und Konservierung der Gemälde und ihres barocken Klimaschhutzes. In: *Barockberichte*. 2002, 32/33, pp. 258–259. ISSN 1029-3205.

36 GRIESSER-STERMSCHEG, *Tabu Depot. Das Museumsdepot in Geschichte und Gegenwart*, p. 47.

designed floor plans, linking of rooms, lighting and equipment, corridor tracking, and the features of administrative rooms.[37]

A depository, the *second heart chamber*[38] in a museum (due to its significance, it is similar to galleries and historical buildings with cultural objects), may be a part of the institution's premises but can also be deployed outside the museum, whether as an existing building or a new building. Another situation is in the case of the "intermediate" depository – an exhibition called *an installed depository*, that is, a part of the storage areas accessible to the public (*Schaulager, live storage, réserves visibles*), which is most often located in the main building. Its history as a type of depository dates to the 19th century when Louis Agassiz founded the *Museum of Comparative Zoology* at Harvard University (Cambridge / Mass USA) in 1859.[39] In the 1970 s, a number of institutions switched to this popular way of presenting their collections. However, at the Museum of Anthropology under the University of British Columbia, its Director, Michael M. Ames, speaks of this solution as *a radical departure from the traditional concept of storing museum collections*.[40] The debate on the appropriateness of setting up installed depositories has been taking place for many decades. In 1990, Paul C. Thistle published a partial review based on analysis of the Canadian situation. He could see the risk in the limited possibility of ensuring environmental stability ("conservation risk"). Also, he mentioned the difficult access for examiners and inspectors, and often poor descriptions of objects, which could give a negative impression of their true value.[41] The text of George Waldemar's study (2014), bears the subtitle of *From history and variants of one hybrid*. Andrea Funck, future Director of the Doerner Institute in Munich, used the same vocabulary regarding

37 *Ibid.*, p. 52.

38 The term by Astrid Pellengahr. PELLENGAHR, Astrid. Das Museumsdepot – die zweite Herzkammer. In: Edd. STÄBLER, Wolfgang and WIEßMANN, Alexander. *Gut aufgehoben. Museumsdepots planen und betreiben.* Berlin München: Böhlau Verlag 2014, p. 9. (9–11). ISBN 978-3-422-07296-1.
WALDEMER, Georg. Zwischen Lager und Ausstellung: Das Schaudepot. Zu Geschichte und Varianten eines Hybrids. In: Edd. STÄBLER, Wolfgang and WIEßMANN, Alexander. *Gut aufgehoben. Museumsdepots planen und betreiben.* Berlin München: Böhlau Verlag 2014, p. 33. ISBN 978-3-422-07296-1.

39 *Ibid.*, p. 33.

40 *Ibid.*, p. 33.

41 *Ibid.*, p. 40.

installed depositories (2017), also writing of *a hybrid*.[42] She noted that neither the optimal environment *(konservatorisch richtig gelagert)* nor the full range of presentation and mediation are satisfied here.

The planning and implementation of *installed depositories* have been, and probably is, a simpler task than the single-purpose specialized repositories in terms of investment approval such as support from the public or responsible politicians. These are mainly the financial demands that matter if they are to be at current technological levels. This also applies to other museum / gallery facilities where it is necessary to ensure the stability of the indoor environment. As an example, the new Research and Restoration Centre in Potsdam (2017) can be mentioned, which has an area of 10 000 square meters and whose cost has reached EUR 31 million, i.e., about CZK 80 600 / m^2.[43]

Depositories can be considered as *the testing stone of responsible museum work*,[44] which is generally true for optimizing the environment for cultural objects in historical monuments, museums, and galleries.

Reaching as far as antiquity, the interest in the proper and safe placement of cultural property, monuments, works of art, and collections of all kinds is accompanied by a gradual broadening of professional knowledge and the formation of specialized professions that play a role in planning the structures to house these cultural objects. They are fields of natural sciences, applied technical sciences, humanities, and specialized professions such as restoration, construction physics, climatology, special design, museology, forensic science, and monument care. These can only fulfil their purpose with dialogue. The aim is long-term sustainable and responsible care for a significant segment of tangible cultural heritage.

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Characteristics of Objects and Materials, Mechanisms of Damage Caused by the Environmental Conditions, Illustrative Examples of the States and Specifications of Damage

VÁCLAV NĚMEC

Collection objects in castles, chateaus, and memory institutions in the Czech Republic represent precious national cultural heritage the value of which is inestimable. One of the main tasks of a developed society is to protect, take care, display, and preserve this cultural legacy as authentic as possible for future generations. Even the most careful and gentle restoration is an intervention in the nature of a material that causes its loss and it is, therefore, desirable to reduce restoration interventions to the absolute minimum. The need for preventive care arises from the above and this care must be adapted to the properties of objects and their material composition in relation to the adverse effects of the environmental conditions which must be controlled in order to prevent the necessity to repair damage sustained. The specific examples below demonstrate the adverse effects of the environmental conditions which are hardly even ideal and cause various types of damage dependent on the material composition of artefacts.

Metal Objects

Metal objects constitute a large material group. The most numerous of them are interior accessories such as chandeliers, candlesticks, tableware and kitchenware, cookware and kitchen utensils, arms and weapons, armours, various decorative objects, and household articles. Another large group includes objects made from a combination of metals having various surface treatments.

Especially hazardous for metals are temperature changes and fluctuations. It means for example situations when a cold object is taken to a warm room, or when warm humid air enters a cold interior, which subsequently causes condensation on the surface of metal objects. In general, higher relative humidity of the air is hazardous for metals.

Corrosion does not only mean the well-known rust on ferrous metals but also aesthetically undesirable products of oxidization on the surface of metals. Surface corrosion is immediately visible and naturally undesirable; however, corrosion processes damaging the deep structures of a metal endanger the very existence of objects, for example pitting corrosion which creates only small holes in the surface of a metal often obscured by corrosion products. A comparatively wide range of corrosion products can appear on other metals. As a typical example we can mention green patina on copper and its alloys, or very unsightly black tarnish of silver sulphide. Tin corrosion is a severe form of corrosion.

Especially metal objects made from more types of metals require special attention as galvanic corrosion could be initiated by higher relative humidity. They must be protected from higher relative humidity to prevent degradation.

Temperature is not critical for the majority of metals. Tin is the only exception where low temperatures (the lowest acceptable temperature is 13 °C) can initiate general corrosion processes but also more serious changes to the crystalline structure of the material. Furniture made of hard wood (e.g. oak cabinets) is not suitable for keeping tin objects because this type of wood produces acetic acid causing deterioration of tin. Acetic acid also harms other metals, e.g. lead.

Metals are not photosensitive. Only excessive exposure to sunlight connected with a local increase in temperature can damage metal objects in certain circumstances, especially if composed of more types of metals having different thermal extensibility.

Unfortunately, it is probably a fundamental human nature that many visitors cannot resist the temptation to touch objects on display. Based on experience from the heritage institutions, metal objects seem to attract such visitors but simultaneously they are extremely vulnerable to corrosion. Human sweat contains salts and highly aggressive acids so that fingerprints are left on the surface due to corrosive effects where metal objects are not sufficiently protected. The most vulnerable of them are armours and blades of cold weapons made of burnished steel. Fingerprints are also clearly visible on copper and its alloys, e.g. brass.

Relative humidity can cause corrosion of painted metal objects and subsequent loosening and disintegration of paint layers and, therefore, irreversible damage to decorated metal household articles.

↑ An example of the effects of higher relative humidity on a metal surface – corrosive products on an alpaca tray (patina)

↑ An example of an oxide layer on the surface of a chalice caused by higher relative humidity and damage caused to the enamel by fingers

↗ An example of corroded metal basket due to high relative humidity which has induced flaking of the painted decoration

↗ An example of the effects of acidic environment and humidity on a tin lavabo resulting in its local destruction

Textile

Period textiles rank among materials extremely sensitive to light, humidity, dust, and acidic pollutants because of organic materials used for their production. Collections of textiles include tapestries, carpets, curtains, bedspreads and covers, upholstery, clothes, liturgical garments, underwear, etc.

On account of the organic materials of period textiles, they are extremely sensitive to all adverse environmental conditions: light, humidity, dust particles, and insects. Light causes fading and change of colours, and also embrittlement of all textile fibres. Silk textiles are especially delicate and damageable.

Unfortunately, damage suffered in this way is irreversible. The only adequate protection against adverse effects of light is to prevent direct exposure to light and to minimize the period of exposure to light.

The worst pollutant having negative effects on textiles is dust.

Dust particles are more harmful than generally admitted. Dust particles are hydroscopic and settle on the surface of textiles where they create acidic or alkaline areas, according to their composition, deteriorating the textile structure. Dust also provides fertile ground for moulds and insects.

Equally harmful are acidic pollutants, especially to cellulose fibres. On the other hand, alkaline environment is dangerous for protein fibres. Sensitivity to acidity or alkalinity must be taken into consideration when selecting proper packaging materials.

An example of the effects of light on the colours and embrittlement of textile fibres

Fine Arts

PAINTINGS TO BE HANGED ON THE WALLS

Hanging paintings are part of every exhibition, belong to valuable furnishings of castles, and are in collections of museums and galleries.

The term painting means especially paintings on canvas, panel paintings (on wood), and paintings on plywood, cupboard, leather, mother-of-pearl, and metal support bases.

The painting proper is usually protected by a layer of varnish on the basis of terpene or synthetic resins.

Collections of paintings can be kept for a long time under conditions which are not ideal but are stable without abrupt changes.

Support bases are usually parts of paintings that are most sensitive to changes in ambient humidity and temperature. Wooden boards react especially to changes in humidity. When humidity is higher, wood swells, when it is lower, wood shrivels, warps, and cracks. Changes in the wooden support base substantially influence the behaviour of the underpainting and other layers of paint. The layers of paint shrink, the bonding agent becomes brittle, craquelure may develop, individual layers of paint lose adhesion and start flaking off the underpainting or even the base, sometimes the varnish film becomes cloudy. If the ambient humidity is very high, wooden, canvas or paper bases may be contaminated with mould. On account of humidity, canvas and paper support bases lose elasticity and strength, become fragile and apt to tear, and may disintegrate.

Paintings should be hanged farther from a source of heat and abrupt changes and temperature and humidity fluctuations should be avoided. From the point of view of long-term protection of artefacts, even occasional heating increasing the ambient temperature above 15 °C is undesirable, whether for the purposes of tours, or conferences and other events. Heat shock is very dangerous for wooden supports that can warp in response to rapid changes in temperature and humidity. Works of art may sustain irreversible damage. It is, therefore, important to maintain a proper combination of temperature and relative humidity of indoor environment according to respective moisture sorption isotherm (to ensure constant water content in an object).

Paintings must not be exposed to high intensity lighting and UV radiation, especially direct sunlight. Ultraviolet rays may damage all paintings, irrespective of the techniques used. Higher luminous intensity, in particular direct sunrays and artificial lighting exceeding 200 lx, causes degradation of the material nature of an oil painting – decomposes varnish pigments and organic pigments contained in temperas and oil paintings and speeds up the degradation process of organic bonding agents and varnishes.

GRAPHICS

When relative humidity is high, the probability that graphics will be contaminated with moulds, bacteria, and insects increases and paper may decompose due to hydrolysis. When relative humidity is low, paper loses its mechanical properties, becomes brittle, cracks and ages. Ageing is caused by cellulose cell degradation and is connected with acid hydrolysis or exposure to UV radiation.

Higher temperature causes that fibres in paper lose elasticity, become brittle, yellow and decompose. Humidity and temperature influence each other and, therefore, they should not fluctuate but be in equilibrium.

In an acidic environment the mechanical properties of paper deteriorate, paper becomes yellow and its gradual chemical decomposition is initiated. Increased acidity of paper manifests itself by yellowing and browning, the development of small or more distinctive yellow dots and spots called foxing (rust chemical ferric oxide may also be involved as ferrous chips from paper machines are contained in paper). Paper exposed to acidic environment becomes brittle, can be torn easily and disintegrates.

Insects benefiting from increased dustiness and dirt represent a real threat to paper.

Proper storage of graphics in a depository is one of the basic prerequisites for their preservation not only because of the environmental conditions.

Loose unframed graphics are the most vulnerable paper artefacts. Their surface is exposed to damage by scratching and loss of the colour (printed) layer. They can be protected by non-acidic paper, or kept in archive boxes. Framed glazed graphics kept in humid conditions of historical buildings or unsuitable depositories can be easily contaminated with moulds.

↑ An example of a painting damaged due to cracks in the wooden support base and flaking of the paint layer

↑ An example of damage to a framed graphic (lithograph) caused by mould formed due to humidity and light (gradual fading of colour in comparison with a print kept in a depository)

↗ An example of the effects of a heat source on the degradation of a painting (oil on canvas)

Wooden Furniture

We encounter objects made of various types of wood and also other materials added to wood, e.g. metals, textile, leather, minerals, ivory, tortoiseshell.

Wood dramatically reacts to fluctuations in temperature and humidity by changes in its structure. These changes are induced by the moisture content depending on temperature and relative humidity of ambient air. Stable environmental conditions are, therefore, the essential prerequisite for an effective preventive strategy.

When temperature conditions change (especially during the transport of objects) rapid and large temperature fluctuations should be avoided.

Natural ventilation of interiors should be provided under controlled conditions with respect to the humidity and must be based on measurements of temperature and relative humidity outdoors and indoors.

Rapid temperature fluctuations have an adverse impact on the volume of wood and lead to wood cracking, loosening of structural joints, and various surface treatments such as veneer, inlay, marquetry, and polychrome.

It is advisable to respect the lower recommended limits of environmental parameters for objects combining more materials, especially wood and inorganic materials the reactions of which differ considerably.

Ventilation should be avoided at periods of big temperature differences indoors and outdoors.

An example of inlayed furniture (Boulle Work) damaged by tensions in the materials due to abrupt changes of the environmental conditions

High humidity and moisture content significantly damage decorative techniques on the surface of wood. It applies especially to the chalk layer under the base for gilding (poliment) and gold leaf which disintegrates and becomes loose if exposed to excess moisture.

Direct contact with water has devastating effects on wooden furniture. Very popular and attractive decoration of interiors with fresh flowers can produce severe defects. Floral arrangements definitely cannot be recommended on period furniture.

Moisture also increases the risk of contamination with mould, pests, and wood-decay fungi; in combination with dust moisture provides fertile ground for wood-destroying insects.

The rule of cumulative effects of light applies to wood just like to all organic materials. It is, therefore, advisable to completely shade interiors open to the public and depositories outside opening or working hours. Extensive and irreversible changes are induced especially by ultraviolet radiation contained in the sunlight, if objects are exposed to it directly and for a long time. We see faded areas on furniture situated close to windows for a long time.

Pottery and Ceramics

Pottery is a chemically resistant and stable material, however, it is hard, fragile, shock-sensitive, sensitive to vibrations, and must be handled with care.

Porcelain is a term used for densely sintered white ceramic products having extremely thin translucent walls impermeable to water and gasses made from a fine mixture of kaolin, quartz and feldspar.

Porous ceramics can be destructed under extreme values of relative humidity or its sudden changes. If water-soluble hydrophilic salts are contained in the body, even increased relative humidity is dangerous (e.g. 60 per cent).

Extreme humidity is hazardous to porous medieval pottery and ceramics with damaged glaze where efflorescence, a crystalline deposit of soluble salts on the surface, may form.

Porcelain is a chemically stable material but if exposed to high humidity or excess moisture, stains may appear in places where the glaze is damaged in the event of a contact with water and abrasion-resistance of gilding may be lowered.

Damaged and subsequently fixed ceramic objects must be handled with special care. Adhesives containing polyvinyl acetate (dispercol) hydrolyse under high relative humidity and produce fertile ground for mould.

Pottery and ceramics rank among materials displaying low photosensitivity, just like metals, stone, glass, enamel, the majority of minerals, and earth pigments.

However, special attention must be paid to photosensitive pigments. Moreover, bonding agents and protective substances used when restoring vessels, are even more photosensitive. Illumination is often connected with an increase in temperature which can be dramatic in interiors facing the sun with large unshaded windows. Increased temperature is connected with lower relative humidity. In light of the above, luminous intensity and exposure to light including ultraviolet radiation should be controlled by means of effective shading systems.

Another threat of damage to pottery is associated with cleaning and exhibition installations when a ceramic object may be temporarily put on the ground. Persons walking there can unintentionally hit it or even step on it. Objects can also be damaged if handled clumsily and carelessly while documenting them.

Ceramic objects with cracked glaze can suffer damage more easily if not properly maintained; the glaze can become loose and flake off.

↑ An example of the effects of light on retouch of added parts of a ceramic sculptural group (colour layer degradation)

← An example of a porcelain vase with fine three-dimensional decorations (Meissen china) damaged by an uninformed person who handled it roughly.

Stone

Stone is represented by vases, sculptures and relief interior accessories in original interiors and collections of memory institutions. Stone is inorganic, most frequently silicate material of natural origin, comparatively chemically stable and resistant. Quality domestic types of stone include crystalline limestone – marble and granite. Imported types of stone are represented by alabaster which was used for free-standing luxurious decorative objects, parts of desk clocks, small reliefs, etc.

Crucial factors influencing the structural deterioration of stone are moisture, abrupt environmental changes, abrasion, acidic pollutants in the ambient air, and vandalism.

An example of the faded surface of a decorative alabaster vase due to long-term effects of air pollutants, especially dust

The Evaluation of the Environmental Effects on Furniture and Furnishings, Measures

METAL OBJECTS

Both metal objects displayed and objects in depositories should be stored under optimum conditions to ensure their protection. Optimum is not the same as ideal but certain environmental conditions in historical buildings can hardly be controlled. In spite of that we can endeavour to eliminate individual factors creating unfavourable or even dangerous conditions for metals. To be able to take an effective action, we have to monitor the environment in which metals are kept and also the mutual influence between individual parameters. Equipment monitoring interiors and various types of other devices able to control and alter environmental conditions can be used. Dry environment (relative humidity ideally up to 40 per cent) and absence of dramatic temperature changes (especially in the case of combined materials) would be optimum.

Regular preservation of metals, e.g. arms, weapons, and armours, is an important preventative measure which should be regularly taken in all historical buildings.

Using proper gloves when handling metal objects should go without saying.

TEXTILE

Silk fabrics and textiles are the most vulnerable part of textile collections because they are extremely sensitive to light and also other adverse environmental factors.

In general, higher temperature speeds up chemical reactions such as acid hydrolysis. It applies to textiles too. Lower temperatures are usually beneficial for textiles especially because of the stabilization of biological damage. Especially rapid temperature fluctuations should be prevented because condensation occurs on the surface of textiles.

The only effective protection against adverse effects of light is to prevent direct exposure to light and reduce the time of exposure to the absolute minimum. It is advisable to apply plastic films filtering out UV rays over the windows, or shade the interiors with suitable net curtains, heavy curtains, blinds, and roller blinds.

The most significant pollutants having an adverse effect on textiles are dust particles.

Textile artefacts should be protected by covers outside the tourist season to mitigate the negative impacts of light and dust on them.

FINE ARTS

All displayed works of art containing natural materials highly sensitive to the environmental conditions show defects of the paper bases in the form of deformations and contamination with mould, wooden bases show cracks and flaking of the paint layers. The influence of changeable microclimate is crucial, especially negative impacts of rapid fluctuations in relative humidity and high luminous intensity.

It is recommended to apply shading systems such as window shutters, Venetian blinds, roller blinds, and curtains to block out sun rays. Special protective plastic films, transparent varnishes etc. filtering out ultraviolet radiation can be applied to the windows.

WOODEN FURNITURE

Wooden furniture is made of natural materials (solid wood, veneer, French polish) and the degree of damage and the state of the furniture are identical with the damage and state of the material it is made of, unless the damage is caused by careless handling by uninformed persons, poor maintenance, or vandalism. The influence of indoor environment on objects displayed is comparable on all tours of historical buildings, especially concerning the adverse effects of higher relative humidity.

Rapid fluctuations in relative humidity cause serious damage to furniture and equipment: cracked and loosened intarsia or marquetry where individual pieces of veneer touch each other, cracked veneer at places of structural joints, loosened structural joints between individual layers of material exhibiting different hygroscopic properties, e.g. sheer stress arises between individual colour layers of polychrome on wood in the event of water sorption which can lead to cracks and flaking of layers. The defects of inlayed furniture where different materials are used, such as brass sheet, tortoiseshell, ivory, etc., include loss of adhesion and changes in the shape of individual inlayed parts.

The most appropriate measure against too high or too low humidity and excess moisture is the natural control of indoor environment based on regular inspections of the state of the building, controlled ventilation of interiors, and, if justified, the application of effective dehumifiers or humifiers which must be regularly checked and operated.

The rule of cumulative effects of light applies equally to wood and all organic materials. It is, therefore, advisable to protect displayed objects by various shading systems during opening hours. Sunlight should be completely blocked out in the interiors open to the public and depositories outside opening or working hours.

POTTERY AND CERAMICS

Pottery is a chemically resistant and stable material; however, particular attention should be paid to objects with damaged glaze which should be handled with great care. Crazing, the formation of microscopic cracks in the glaze, also requires special attention. Dust and other pollutants can penetrate the fine racks and a visible network in the glaze occurs. Another group of objects that must be handled with proper care includes ceramic objects not intact any more to which additional materials have been added during restoration.

The objects housed must be protected from dust that can contain substances aggressive towards glaze and ceramic paints. Dusted surface becomes moist more quickly and can be affected by pollutants contained in the air and the dust.

STONE

Stone in the interior does not require any special measures. Routine maintenance and dust removal by a vacuum cleaner are sufficient. It can be recommended to keep alabaster artefacts in showcases and display cabinets to prevent dust from settling on them.

Conclusion

The common denominator of all objects on display or in depositories is their composition usually combining natural and metal materials (except some fine arts and free-standing metal objects). Regardless of their composition, all objects in exhibition areas of interiors open to the public, or depositories are exposed to environmental conditions characterized by higher relative humidity exceeding 70 per cent because these areas are not warmed up due to technical and economic reasons, or inoperative technical equipment of buildings. However, the exposure of more sensitive materials (paper – graphics, paintings on wood and canvas) to light and humidity can lead to more serious deterioration of them. The most devastating effects arise from rapid fluctuations in relative humidity (5 and more per cent in few hours), which results in the loss of adhesion of veneer on the surface of furniture, cracks in wooden structures of furniture reflected by cracks in surface veneer, warped paintings on canvas and graphics including passe-partout, and cracks in wood bases of panel paintings. The adverse effect of high relative humidity shows in the form of corrosion products on metal objects (arms, weapons, armours). We cannot omit the microclimate in showcases and display cabinets where objects (e.g. graphics placed under glass in picture frames) can be contaminated with moulds. Last but not least, we have to mention the adverse effects of handling by curious, uninformed (and incorrigible) people, and damage caused by vandalism.

It is possible to prevent all negative effects by taking reasonable and affordable technical measures such as monitoring and control of indoor environment, sustained attention and care of the qualified staff members of cultural heritage and memory institutions who use procedures and means enabling them to maintain furniture and collection objects in a state that is permanently as good as possible.

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Pest Management

MICHAL MAZÍK

Introduction

Biological pests occurring in many different forms and species are a serious problem in preserving movable cultural heritage. Their presence is natural and forms a very important part of the natural ecosystem. In the living environment, there are life forms that usually help break down natural polymers, making a significant contribution to the return of some chemicals to the ecosystem.

When trying to preserve the material form of cultural objects, however, this property is undesirable. The term "biological pest" may also include all human influences as yet another type of animal when large amounts of resources are currently being spent to protect collections from its unwanted activities (theft, vandalism). From the general view of the biological attack on cultural objects, two basic types can be distinguished. The first type is a direct biological attack when the pests are trying to metabolize the components of the object. The second type is indirect when secondary damage occurs due to metabolic products or another activity of the pests. Distinguishing these directions makes sense in the preventive protection of cultural objects, especially when preventive agents are directly applied on the object. Thus, in the case of a direct effort to decompose the material of the object, it is direct protection of the material of the object most often by chemical means, which are intended to reduce the probability of attacking the object. Concerning the indirect attack, these are usually elements of preventive protection that are not applied directly on the object.

Of the possibilities how to view the issue, the view considering the material composition of the predominantly attacked objects is fundamental, as well as the issue of the climatic conditions for the biological attack of collections. The material specification of biologically attacked objects is given by the natural environment in which the pests are normally found. Thus, it concerns objects from natural materials or materials that have been produced by processing from natural raw materials and at the same time they are exposed to similar environmental conditions as in the living environment. To name some of the materials, they are natural carbohydrates and proteins. Concerning the environment, it is especially high relative humidity. If these demands for energy sources and the environment are met, the attack is usually a direct attack on objects. However, an indirect biological attack may include any material in any environment, for example, the formation of a microbial sulphate metabolite (H_2S) and its effects on materials (e.g. silver).

Climatic conditions for the development of biological attack are also determined by the conditions of natural occurrence of pests. One of the most important parameters is the relative humidity of the environment and the associated temperature. This parameter is common for all types of biologically active effects.

In living organisms, one of the key factors is the reproduction strategy. Knowledge of breeding cycles which usually depend on the season, and, generally, on climatic conditions is crucial for the successful detection, localization and elimination of biological pests.

A major drawback concerning a biological attack on a collection is the impossibility of early detection. It is usually associated with optical, chemical, or mechanical changes in material. Detection of biological attack is therefore also rather indirect. Direct detection options require examination with UV radiation, scavenging, cultivation, or direct observation. However, a biological attack can be predicted on the basis of the environment climatic parameters, mainly increased relative humidity, such as the occurrence of fungi in high RH environments in different temperature ranges. The ability to detect is also closely related to the knowledge of the migration of higher animal species in particular.

This information, along with conforming to general hygiene principles, also helps to provide the main preventive measures against the occurrence of biological attack. The elimination of migration routes is one of the simplest measures, but it is difficult to implement, especially in historical buildings. The solution with the help of chemical and physical methods of remediation requires professional intervention. These measures do not fall under preventive care but should be part of conservation-restoration intervention. Methods of remediation are generally divided according to the method of the body's killing, either chemical or physical. Chemical remediation may also be preventive in processes where the active substance or mixture of substances remains in the object's material even after intervention. Physical remediation methods do not usually have a long-term effect. From the point of view of preserving cultural objects, the remediation of biological influences is highly risky and for the vast majority of objects the scope, the type, and the method of remediation must be carefully considered to avoid damaging the object.

Classification and detection

The biological pests can be classified by species-related relationships using the classical taxonomy, i.e. division into categories of world, branch, class, order, family genus, species. In practice, however, the identification of biological activity on cultural objects is not based on the primary identification of species classification, but rather on the characteristics of the effort to metabolize these objects. It is therefore appropriate to treat these factors together. The objects are primarily natural organic materials that are metabolized by a combination of mechanical and biochemical processes. These processes leave specific features according to which biological activity is primarily identified on cultural objects. A frequent problem is the complicated timing of these manifestations. For example, holes and chewing marks are clear manifestation of woodworms, but this manifestation does not necessarily prove the topical activity or the presence of a woodworm. Other signs are excretions, faeces, or other metabolic products. The signs indicating a biological activity may also result from an adaptation of the environment (biotope) by a biological agent, such as nesting, burrow formation, or passageways in the wood. Alternatively, they could be the very remnants of biological pests – the body, cast skins of the insects and the remains of higher animals such as feathers, bones, fur.

Another possibility of bio localization is the identification of migration routes, as it is very often the penetration of biological agents from the external environment. These are mainly migration routes such as ventilation shafts, piping or other utility networks (Figure 6). A very well-known route is through the windows where especially double windows create a natural mechanical trap in which mainly insects get stuck. These natural mechanical traps contain a sample of migrating insects and can be used for detection. They are also suitable for setting traps that serve directly to detect biological agents. The principle of trapping may be different, but it is always based on a movement restraint for the required biological agent. Traps are also placed near materials or objects in risk. For climbing insects, placing the traps in the corners of the room is advisable. Baits and traps should allow identification of the latent biological agent (or its residues) in order to allow for their taxonomic determination.

For animals that are expected to have a degree of intelligence, such as rodents or birds, the methods and forms of trapping need to be changed from time to time. Traps and baits are also considered as remediation options, but their effectiveness is relatively low. Therefore, some of them use a strategy of luring biological agents to traps to increase their effectiveness. Luring is carried out with pheromones, food, light. In these "active" traps, however, their potential negative impact on other cultural objects (e.g. the risk of increased attracting of these pests from the outside) should be considered. An overview of the occurring biological species according to their taxonomic relevance, together with the possibilities of their detection and the specification of the endangered material, is shown in the tables below.

Fig. 1 and 2: Demonstration of the placement of the climbing insects' catcher.
On the right: Kunštát National Monument.
On the left: Sanitary room of the Moravian Gallery (hereinafter MG) depository.

FUNGI AND BACTERIA

These are simple life forms that are important natural polymer decomposers. The issue of fibrous fungi and insects is one of the most frequently monitored preventive conservation factors, especially in historic buildings.

In relation to cultural heritage protection, fungi attacking wood are important, which are divided into wood-staining, wood-destroying and lignolytic fungi. These fungi are a repeated and long-standing problem, especially in relation to preservation of listed buildings. In this area, dry rot is notorious. Part of the large group of fungi are so-called fibrous fungi, also called moulds. These forms of fungi are characterized by the formation of mycelium growing through the substrate that they metabolize. Their presence is mostly associated with high humidity, warmer environments and low airflow. The most abundant fibrous fungi are listed in Table 1.

The development of fungi can be very fast, even in the order of hours. The initial phase may not be accompanied by visible signs on the surface of the attacked object. In addition, the form of reproduction through spores is very effective and the development of microscopic fungi occurs almost everywhere where appropriate climatic conditions are created. Different types of fungi can cause serious damage to health (depending on mould concentration and exposure time). In microbial attack, detecting odours is possible due to the formation of gaseous metabolites such as hydrogen sulphide or ammonia. A good example is formation of a specific, very humid microclimate without air flow needed for fungi development, which is accompanied by the well-known musty odour.

Although moulds occur in a wide range of temperatures, the development of these specific microscopic fungi is very closely related to the amount of water vapour in the environment. In general, they occur at relative humidity of about 65% and above. In practice, however, managing microclimate conditions can be difficult, especially due to their seasonal fluctuations, which result, in particular, from the nature of historic buildings (e.g. unheated spaces). In addition, the interior equipment and the construction of cultural objects itself enable formation of various microclimates in which favourable conditions for the growth of fibrous fungi can occur (for example, a local environment with increased RH enabling growth of fungi is created around the photo on paper support in a glass frame even though the interior RH values are below 65 %).

TABLE NO. 1: COMMON FIBROUS FUNGI IN INTERIORS OF LISTED BUILDINGS

Common fibrous fungi (mould)	High-risk material	Detection insight mycelium	Type of damage	Activity and type of propagation
Penicillinium spp	All natural materials	Different colour shades	Enzymatic decomposition	Spores, activity above 65 % RH
Aspergillus niger	Food, carbohydrate-containing materials	Black	Enzymatic decomposition	Spores, activity above 65 % RH
Mucor spp.	All natural materials	White fluffy moulds	Enzymatic decomposition	Spores, activity above 65 % RH

Fig. 3: The tram handle was damaged by a fibrous fungus (mould), the object was exposed to a local flow of air with high RH. From the TMB collections.

INSECTS

Insect belongs in the class of arthropods, characterized by six limbs, often an ability to fly and reproduce sexually. Their articulate body with an exoskeleton from chitin and proteins has nervous, circulatory, digestive, reproductive and respiratory system. The problem species in terms of protection of cultural objects are summarized in Table 2. They occur in three developmental stages: an egg, a larva and an adult individual. They attack every natural material.

Chewing marks of insects are particularly noticeable on the damaged material and around it. Bodies of dead animals or the remains of various parts associated with the development stages of insects such as cocoons, cast skins, etc. can be observed, too. These traces can be seen especially near food sources. We also find them on the routes of migration channels such as windows (especially flying insects), wiring shafts, joints and non-insulated connection openings, such as radiator (hot-water) pipes, water pipes, etc. Adhesive or mechanical glue traps can be placed in these locations.

When insects are not visible, it is advisable to place traps in the corners of the rooms and places that create natural obstacles for climbing insects. Glue traps can be used to catch flying insects, too. They contain the respective pheromone (which attracts only a particular type of insect) or aromatic substances that resemble the smell of food. These traps are checked by the staff, depending on its capabilities and the seriousness of the suspected presence of insects. The natural adhesive-mechanical traps are, for example, webs or open water surfaces where different species of flying and climbing insects can be observed. Traplights can be used to catch flying insects. These traps work on the principle of spatial orientation of insects focusing on the strongest light spot (the sun or the moon). For good visibility (trap efficiency), a long-range blue light with overlapping into the UV area is used over long distances, so it is not appropriate to place sensitive cultural objects in its proximity. Traplights use a high-voltage metal grid to kill the attracted insect, a potential source of ozone. They are best suited for access halls, sanitary rooms, lockers, kitchens, etc.

TABLE NO. 2: SELECTED INSECTS AS BIOLOGICAL PESTS.

High-risk Insects	High-risk material	Detection	Type of damage	Activity and lifetime, high-risk developmental stage
Wood-destroying worms *(Anobium pertinax Linnaeus and Anobium striatum Olivier)*	Wood, protein glues, paper	Chewing marks, chewing channels of approximately 3 mm in diameter	Mechanical, wood-decaying fungi are often deposited in the channels	Spring to autumn, insects winter and lives up to 1–3 years, active mainly at night, only larvae cause damage
Old House Borer *(Hylotrupes)*	Wood	Chewing marks	Mechanical, wood-decaying fungi are often deposited in the channels, attacks especially coniferous wood	Spring to autumn, insects winter and lives up to 2–4 let, only larvae cause damage who are able to live up to 15 years
Common Cloth Moth *(Tineola bisselliella)*	Textiles – in particular animal fibres (wool)	Chewing marks, cocoon residues, excretions, dead bodies of adult in-sects; pheromone, glue or light traps above the ground near the infested material	Significant loss of mechanical cohesion of textile bonding, textile contamination by metabolic products	It is able to operate year-round, but it usually occurs from winter to spring, night activity, only larvae cause damage, lives up to 1 year
A silverfish *(Lepisma saccharina)*	Paper, material rich in carbohydrates and proteins	Chewing marks, dead bodies of adult insects; glue traps on the ground in corners monitored rooms	Chewing marks, paper contamination by metabolic products	It is able to operate year-round, night activity, lives up to 1 year and it occurs only in places with high RH
Book lice *(Liposcelis divinatorius)*	Synantropic, eats fungal mycelium, its biting apparatus capable of destroying paper	Chewing marks, dead bodies of adult insects; glue traps on the ground in corners monitored rooms, very small (1 mm)	Chewing marks, paper contamination by metabolic products	It is able to act all year round, night activity, lives up to 1 year and it occurs only in places with high RH
Desmestes lardarius L. *(Dermestidae)*	It focuses on wool, skin, feathers, horn and similar natural materials, it feeds in all stages of development, lives in bird nests and carrions	Chewing marks, dead bodies of adult insects, live larvae up to 1 cm long; mechanical glue traps on the ground in corners monitored room,	Chewing marks up to 0.5 cm, metabo-lic products, larvae residues, due to its size, it causes the loss of mechanical properties, such as in parchment	It feeds in all stages of development, larvae can live up to 2 years, at room temperature capable of acting all year round

Fig. 4: Damage to a book caused probably by a worm

RODENTS

They are the most widespread group of mammals with their characteristic teeth arrangement. Typical representatives are in Table 3. In protecting the cultural heritage, it is especially the mouse family, which belongs to the youngest rodents from the evolution point of view. Their other characteristic is small size and great fertility due to a short period of gestation and a high number of pups. They are omnivorous and cause damage not only by eating biological collections, but also by the need for constant sharpening the front teeth, especially through wood gnawing. They also damage objects that are not part of their diet.

Other indirect negative effects are through their excrement and the production of undesirable pollutants that can contaminate cultural objects. In rodents, therefore, the presence of chewing marks with signs of gnawing (traces of their front gnawing teeth are often detectable on the material) and excretions in the form of typical faeces. Depending on their size, the size of the rodent can be deduced, the species, and thus follow-up measures can be adapted (e.g. a mouse trap will not be effective in the case of a rat). These traces are located along the migration channels and the feeding places where the source of their activity ("nest") can be traced and the effectiveness of traps or baits can be enhanced.

TABLE NO. 3: RODENTS

High-risk rodents	High-risk material	Detection	Type of damage	Activity and lifetime
House Mouse *(Mus musculus)*	All materials except glass and stable minerals	Faeces up to 5 mm	Gnawing, contamination by faeces	Active in the evening and at night, lives up to 1.5–3 years
Brown Rat *(Rattus norvegicus)*	All materials except glass and stable minerals	Faeces up to 5 mm	Gnawing, contamination by faeces	Active in the evening and at night, lives up to 2 years
Black Rat *(Rattus rattus)*	All materials except glass and stable minerals	Faeces up to 5 mm	Gnawing, contamination by faeces	Active in the evening and at night, lives up to 2–2.5 years

BIRDS

They are warm-blooded vertebrates characterized by one pair of legs and three-fingered forelegs turned into feathered wings. Their toothless beak and the ability to fly that some bird species have lost are also characteristic.

In the area of cultural heritage care, it is nesting and the bird droppings that cause problems. The droppings are rich in soluble salts (nitrates, phosphoric salts), which are the source of salinization of masonry, plasters and especially sandstone sculptures. They accelerate corrosion processes on metal elements or entire metal sculptures. Birds stay in elevated, hard-to-reach places where they also build nests. Building nests is accompanied by collecting very diverse materials from the surrounding areas, which can cause problems with technical and construction elements in buildings (for example, reducing air-handling system efficiency). Detection is not complicated. The natural movement and the presence of birds in the daytime can be detected by their direct observation.

Fig. 5: Bird droppings after penetration of birds into the technical areas of MG depositories, providing sources for the development of microbiological or insect biologic activity or for direct aggressive effect on buildings or materials of cultural heritage.

Preventive measures

The prevention of biological damage is very closely related to the observance of hygienic regime principles and optimal microclimatic conditions (i.e. relative humidity and air temperature, cleanliness of the environment, eventually lighting conditions). Here, especially authentic historical interiors have suitable conditions for biological attack. This is due to the limited possibilities of regulating the climatic parameters of the environment and the presence of a suitable substrate, which is the various organic materials that are attacked by biological pests. In interiors where it is possible to choose equipment to minimize the risks of biological attack, no plants, carpets (especially wool), domestic animals, free food, litter (not only in the absence of hygiene, but also in locating waste baskets, etc.) are appropriate. Placement of real food in exhibitions or the proximity of food machines, kitchens or other food sources are also to be reconsidered.

An important preventive measure is a special regime for moving objects, especially from the outside to the inside. Therefore, besides a thorough examination of a new object (or an object returned from a loan), its quarantine is recommended, which increases the possibility of detecting a biological attack. There are also regular preventive checks of all objects, which are often carried out within the inventory check.

Optimal environmental conditions are also related to the construction and technical features of the space. In this context, it is advisable to prevent the entry of biological pests by consistent sealing the outer walls, holes, cracks, channels, and by inserting nets into chimney shafts, ventilation shafts, skylights, windows, condensation drain openings, etc. Barrier external protection in the form of nets, needle-shaped barriers to prevent birds from resting, audio bird scaring devices, or devices resembling bird predators (silhouettes of birds of prey stuck on glass). An important factor is also compliance with hygienic principles and health protection of workers in the remediation and handling of objects that have been treated with agents against biological pests (e.g. residuals of remedial agents in the rooms, objects treated in the past with now forbidden means such as DDT, arsenic salts, etc.), and when placing poisonous traps.

Fig. 6: Demonstration of the possibility of insect migration through insufficiently blinded electrical wiring with a laid-on insect trap.

Remedial measures

If the microclimatic conditions are inappropriate, a food source is found or prevention is insufficient, it is necessary to actively proceed to prevent the spread and elimination of biological attack. There are a number of procedures and a whole range of methods of eliminating fungi, microorganisms, insects and higher animals. When making a decision, the approach to the principle of methods is based on chemical or physical effect.

Chemical remediation is an application of a chemical that has a specific desired effect on the lean biological pest. In the case of chemical remediation, the possibility of transporting the active substance with the desired effects to the source of biological activity is crucial. For this reason, remediating methods using gases are highly efficient. Another option is to apply the active substance solution in different ways. The most common are spray forms (aerosol), coating, or various forms of pressure grouting into damaged material. Common and frequent poison baits for both insects and rodents are part of the chemical remediation. When applying chemical agents intended to control biological activity, it is essential to stick to the recommended doses of the active substance, in a way that allows its interaction with the desired form of biological activity. Therefore, both appropriate season should be selected and the mechanism of remediation should be adapted. It has the greatest impact on insect elimination, when the appropriate season must be chosen for remediation, but also the right type of insecticide, acting on the correct development stage of insects. For effective transport of the active substance, the contact form is frequent, where the aerosol (spray, smoke) of the active substance paralyzes or directly kills the whole spectrum of insect development phases. In higher animals, especially in rodents, inhalation of the active substance is expected when applying the gases. The control of fungi and bacteria with gases is difficult.

Means that do not cause death directly have an effect mainly on reproduction or degeneration. This applies in particular to disinfectants. Solution chemicals have the greatest application in disinfection, i.e. control of bacteria and fungi. Nowadays, disinfectants are mainly surfactants, alcohols and oxidizing agents based on sodium hypochlorite or hydrogen peroxide in water. For all types of chemical remediation, their suitability for the possibility of unwanted chemical interaction with materials of cultural objects should be considered. Complete remediation of entire interior spaces by gassing is especially risky. A good example of this is the popular and low-cost application of gassing through the smoke bomb that spreads the active substance to the environment by exothermic reaction of chlorates with the oxidizing component (starch). However, solid particles of chlorides, which significantly affect the corrosion speed of metal surfaces, also propagate into the space together with the active substances initiated by heat.

Application of chemical means can therefore be risky and it is advisable to use the correct application strategy or selection of the remedy. At present, emphasis is also placed on the medical load of the applied means, i.e. their minimal toxicity to humans. The impact on the environment should also be assessed.

Application of inert atmosphere and the use of physical methods is an interesting alternative to minimize the impact of chemicals on the remediated objects. Elimination by inert atmosphere is mainly used for insects that act outside materials. It is on the dividing line between the chemical and physical methods of remediation of biological pests. It results from long-term inhibition of metabolic activity of insects to death in conditions with minimum oxygen content. Remediation takes several weeks and is demanding in terms of consumption of inert gases (N, Ar, CO_2).

Physical methods are based on a change in the physical properties of the environment or use different types of electromagnetic radiation. An example of a change in the physical properties of the environment is the effect of increasing or decreasing the temperature to a threshold when it is fatal for the living organism. The destructive formation of crystalline ice in tissues or the thermal denaturation of proteins is used. Microorganisms and fungi, especially their inactive forms (spores) are relatively low-sensitive to temperature due to the effectiveness of the method.

Methods of heating or freezing are primarily intended for insect destruction, desensitisation. The method of thermal remediation involves warming of the remediated environment to a temperature above 50 °C. Freezing takes place at temperatures of -15 °C and below. In remediation of hygroscopic materials in particular, managing the process of controlling relative humidity values in order to avoid undesirable physical and mechanical changes of the treated material are essential. In practice, special freezing chambers or chambers for heating are applied.

In the case of thermal remediation, mobile remediation options are also used, when a hot air-filled tent around the whole or part of the remediated building is put up. The drawback of this method is that the air temperature in the remediated areas must be substantially higher than 50 °C to achieve effective temperature values inside materials (such as wood), due to the low thermal conductivity of the conventional materials, especially wood which generally forms the largest part of the remediated material.

In the methods based on temperature changes, it is essential to assess their effects on objects that contain materials or decorative or structural elements that could be affected by heat effects, i.e. heat-sensitive materials and mainly physical and mechanical changes related to the water content of treated objects.

Physical methods based on the use of specific electromagnetic radiation can also be divided into two general categories that affect the treated material. Short wavelength (gamma, x-ray, ultraviolet) radiation that has high energy and can chemically interact with the materials. Thus, practically bring about changes in structure, colour, and chemical composition. However, this is also the principle on which unwanted biological pests are destroyed. High energy radiation causes structural changes at the DNA level, creating oxygen radicals, OH radicals, and other highly toxic radicals for biological processes. Therefore, the treatment is specific for its high efficiency and short remediation time. The gamma-ray remediation based on permanent radiators, especially the Co60, is still popular and frequent, and commercially available. In terms of material sensitivity, it is not suitable for glass, paper and can cause colour changes on some pigments. It is interesting that this method was completely abandoned in the neighbouring countries, despite a number of indisputable advantages of this remediation method, because of potential negative effects on health and the environment.

A physical use of electromagnetic radiation for the remediation of cultural objects that does not affect chemical composition of the treated material is, for example, the use of microwave radiation which interacts with materials by modulating the kinetic energy of molecules in materials. This mechanism is especially applicable to materials containing water, especially for living organisms. It is manifested by a local increase in temperature, even inside the materials, which is applied when eliminating wood-destroying insects acting deep in the structure of the wooden sanitary object. Problem is the interaction of microwave radiation with metals in this case. Metals, due to their properties, are heavily heated by microwaves and can initiate burns. Therefore, this method can only be used when there are no metal elements.

The solution with the help of chemical and physical methods of remediation requires professional intervention. These measures do not fall under preventive care but they should be part of the conservation-restoration intervention. The possibilities of remediation of biological attack are highly specific depending on the type of attack and the type of material infected. Biological remediation strategy should be planned sufficiently and should combine economic and health-environmental requirements.

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Improving the Indoor Climate of a Special Depository with a Simple Construction Modification

MARTIN MRÁZEK, JANA FRICOVÁ

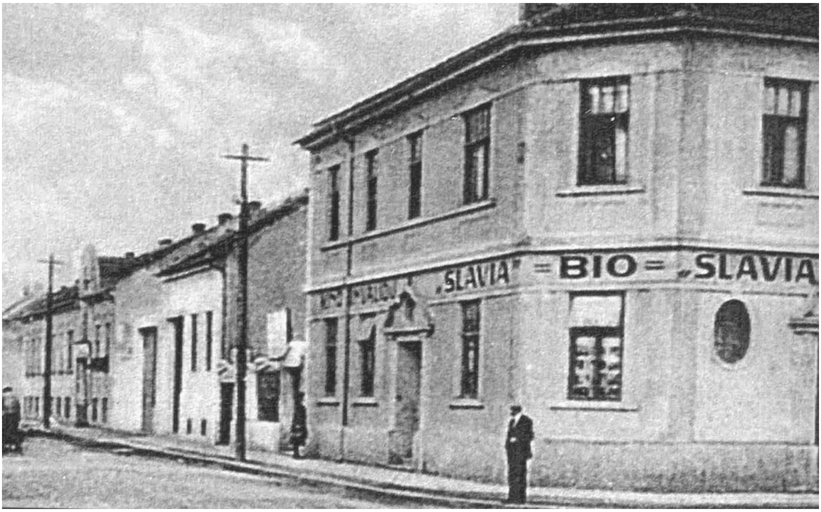
Abstract

The text is based on a case study dealing with the Technical Museum of Brno (TMB) depository in Židenice compiled under the NAKI project – Methodology for preserving cultural property – optimizing conditions to achieve long-term sustainability DF13P01OVV016. This special depository is used to securely store collection objects comprising combined materials. The objects stored are a combination of leather, wood, and metal – materials requiring different humidity and temperatures for optimal long-term storage. The monitored area demonstrated increased levels of moisture, mould also being detected there. It was necessary to find a quick and cost-effective solution to improve the internal climate. Finding a solution to the situation became the subject of an experiment in a case study.

History of the building

The existing building is probably located on the site of the original Grand Bio Astoria cinema in Jungmannova Street (in 1933 the street was renamed to Rokycanova), which opened in 1912. In 1941 the name was changed from Bio Slavia to Sport. Under this name, the cinema ceased operation in 1966 due to safety faults in the electrical wiring and problems with its running, especially heating and ventilation. In 1970, state authorities decided to transfer this building to the TMB, and in the same year, a detailed design was carried out by the Morenda company to redevelop the depository. Construction work was completed in 1972. Conservation workshops were built as part of the redevelopment. They are partially located directly in the depository building, but most of them are in the vacant space created after closure of the boiler room, where other premises necessary for their operation were built and added.

At the beginning of the 1980s, a faulty roof truss with suspended ceiling above the original cinema hall was found. A temporary solution was found at the beginning of 1983 by reinforcing the truss and suspending the ceiling in the form of a lattice structure. The ceiling was then inspected regularly. In 2010, the façade was rebuilt, and a structural assessment report was prepared detailing the seriousness of the depository ceiling's condition. In 2014, the broken ceiling was stabilized and buttressed with a system of wooden supports.



↑ View of the Bio Slavia cinema building, 1920s. Source: Archive of the Technical Museum in Brno

↑ The TMB depository and conservation workshops, view from the intersection of Rokycanova and Kaleckého streets after restoring facades and replacing windows in 2010. Source: archive of the Technical Museum in Brno.

Technical and physical aspects of the building

The depository building is located at 33 Rokycanova street in Brno – Židenice. It is integrated into an urban terrace-house development. It forms the corner of Rokycanova and Kaleckého Streets, whose longer side faces south, its shorter west.

In terms of external risk analysis, the impact of the environment is negligible. No factories or production facilities are nearby, only ordinary urban traffic. Due to a high level of groundwater, it must still be pumped out from the basement rooms below the building. Water is drained to a central sump and pumped automatically to the municipal sewage network. Considering the impact on the local climate of vegetation and traffic, the demand on the structure is quite normal.

Description of the building

The structure was originally designed as a cinema with housing units. After reconstructing the cinema as a depository, the building is divided into three parts. The entry section, depository, and conservation workshops. The whole building is built from brick and is a three-storey structure comprising ground floor, second floor, and third floor with dormer window where the roof faces the courtyard. The building is equipped with a basement in one section and a closed yard. Floors and stairs, according to the nature of their use, are made from terrazzo, concrete, epoxy, PVC, wooden floorboards, or parquetry. Walls have a classic lime-cement plaster, and the ceiling is made of wooden beams with plastered ceiling boarding. The ceiling in the workshops and in the construction inside the cinema which replaced the balcony is formed with steel I-profiles and Hurdis moulded bricks without plaster. The parts of the building overlooking the street and the flats in the yard are fitted with plastic double-glazed windows. Other windows, such as those overlooking the yard, are the original wooden windows. Wooden ridge trusses are above the original cinema, reinforced with scaffolding pipes on which fired roofing tiles have been laid.

The entrance and the first part makes up the first floor, which has two accesses to the house, conservation workshops, and depository. The depository area forms the administrator's office and then the depository itself. The depository comprises the original cinema foyer, which is connected to the cinema screen and preserves the height proportions of the whole building. This can be considered the second part of the building. The balcony was pulled down and a load-bearing steel structure was built into the space thus created. It forms about half of the original hall and creates a gallery separated from the rest of the room by a wall at its upper section. These areas can be entered via the original staircase that led to the balcony and to the projection booth. As a result, a depository space of 910 m² was created. Material for 305 steel adjustable shelves and two cranes were employed to install shelving for the full six-meter height of the building. Double-winged insulated doors made of sheet metal exit into Kaleckého and Rokycanova streets. Along the hall of the original cinema on the northern side are offices, immediate storage, and individual workshops and studios, with storage rooms and sanitary facilities both on the ground floor and first floor entering from the yard. However, part of this area can be accessed from the conservation workshops through the depository and a corridor of wire mesh. The third part of the building is formed by the individual conservation workshops, which were completed on the site of the vacant space resulting from the boiler room ceasing to be used. A backyard is inside the building. At present, the indoor climate is monitored with Commet Data Loggers.

The building is currently in an emergency condition. The structure is compromised at its foundations, the statics of the truss and the suspended ceiling are disturbed, and the roofing is about to collapse.[1] In 2014, the ceiling was stabilized with wooden supports. The building should have been vacated for several years as part of the implementation of the project of the Methodological Center for Conservation and the Central Depository in the former military barracks in Brno – Řečkovice, which only took place in 2017.

The only documentation currently available of the building is from the redevelopment in the 1970s as the Morenda implementation project.

After announcing the emergency condition of the roof above the depository, a new approval (a building occupancy certificate) of the building at number 33, Rokycanova Street was prepared in August 2014 (15599/33 cadastre Brno-Židenice).[2]

1 Rating grade: 4, according to National Heritage Institute rating.
2 Number 1804/40–14 Ing. Bořivoj Hložek / Ing. Hana Žouželová.

Technical and physical aspects of the assessed space

SPECIAL DEPOSITORY NO. 3

The floor is concrete, the ceiling comprises wooden beams, ceiling board, and reed, and plastering on the walls and ceiling is lime-cement. The space is heated with a radiator connected to the gas boiler distribution system. Air flow is provided by two ceiling fans near Depository No. 2. The space is illuminated with ceiling bulbs. A dehumidifier T40 / TE40 (40 l / hour capacity) and a datalogger are installed in the middle of the room at a height of 120 cm above the floor. The depository is equipped with special wooden stands for collections with combined materials – militaria. These are mostly collections from the 19th and 20th centuries. (metals, wood, leather) – civilian and military firearms, all gunlock systems.

INDOOR ENVIRONMENT

Due to the location of Depository No. 3 within the first and second depositories, the initial conditions of the indoor environment based on this dependence must be considered.

TECHNICAL AMENITIES AND EQUIPMENT

The electrical wiring dates to 1985 and is subject to regular inspection. Twelve 200 W bulbs are along the perimeter of the walls and four mercury discharge lamps on the ceiling. Until 2008, the room was maintained by 12 heating units, which are now out of order. Water and gas distribution systems are inside the walls of the depository. The air is only naturally exchanged. In January 2013, this whole space was equipped with 4 COMMET data loggers to measure relative humidity and air temperature (RH / T), and in March 2013, with another data logger to measure the external parameters of RH / T.

Based on the RH and T measurement records (February 2013–March 2014), an average annual RH of 51 % and temperature of 15 °C can be estimated. In winter (November–April), the temperature ranged from 10–15 °C and in summer 15–25 °C. Relative humidity was evaluated using monthly moving averages, achieving 43–55 % in winter months[3] and 55–65 % in summer. The transition between individual cycles corresponds to an acceptable fluctuation of a maximum of 10 % in one month (April–May).

3 In a simplified annual record, the winter cycle (November–April) and the summer cycle (May – October) are considered.

TYPOLOGY OF STORED OBJECTS

Mixed Depositories No. 1 and 2 contain a variety of objects covering different subjects such as crafts, household equipment, textile machinery, chemical fields, foundry industry, etc. The material combinations comprise mainly iron, non-ferrous metals, wood, leather, and paper[4].

INDOOR MICROCLIMATE

The average annual RH is higher than in the surrounding Depositories No. 1 and 2 and achieves around 58 %, the temperature being 16.7 °C.

During the winter cycle (November–April), the temperature ranges from 12–15 °C, and in the summer cycle 15–22 °C. Relative humidity was evaluated from monthly moving averages, achieving 43–55 % in winter and 60–70 % in summer. The transition between the individual cycles corresponds to a fluctuation of about 15 % in a single month period (April–May).

EVALUATION OF RISK FACTORS

The space in Depository Nos. 1 to 3 is relatively thermally stable thanks to a large area of concrete floor. The transition between winter and summer cycle is accompanied by an acceptable fluctuation of ± 10 % in RH. According to the ASHRAE's classification of depositories, this depository area can be ranked in terms of risk as category B, possessing medium risk of mechanical damage to highly sensitive materials and low risk to moderately sensitive materials.

However, risky RH increases above the 70 % limit occur when the external temperature is significantly higher than the indoor temperature during the summer months. In Depository No. 3, mould develops on the surface of objects owing to low air circulation and increased summer humidity. Therefore, regulation of the interior air with a dehumidifier and building vents was recommended.

The entire depository building, especially the open spaces of the Mixed Collections Depository Nos. 1 and 2, carry the load from operating the building itself and the technological areas of the conservation workshops. The spaces are only separated with a woven wire partition for safety reasons.

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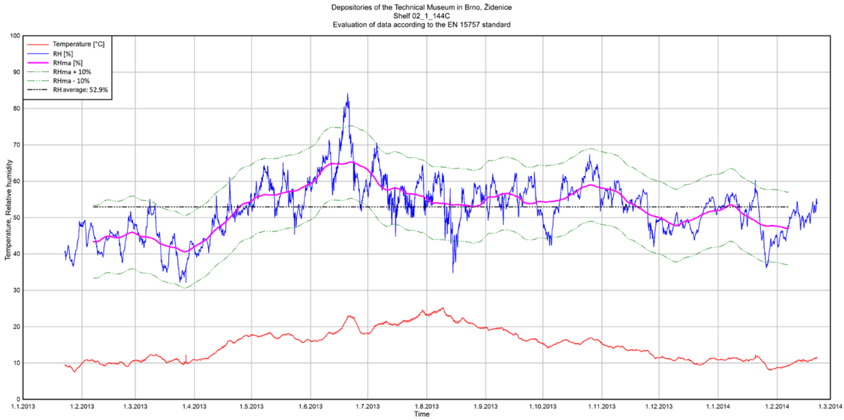
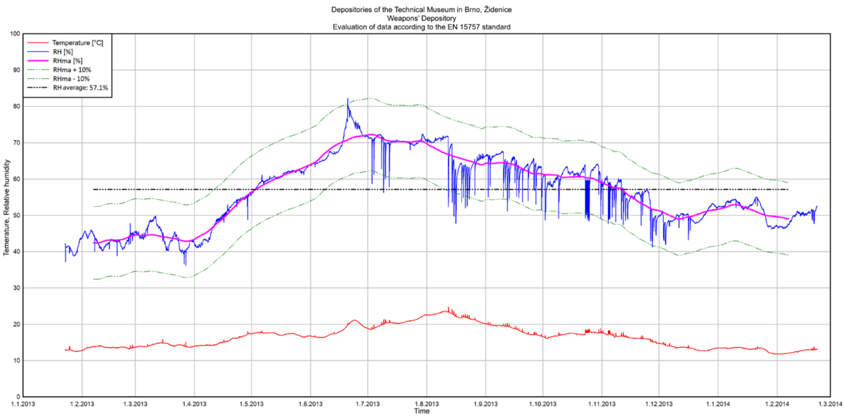
4 SELUCKÁ, Alena. *Současné standardy mikroklimatu v muzejní praxi* (Current standards of microclimate in museum practice) In: Fórum pro konzervátory-restaurátory (Forum for conservators-restorers; journal) 2014. Brno: Technical Museum in Brno, 2014, pp. 71–76. ISSN 1805-0050.





↑ RH/T records from Depository No. 2, sensor No. 07931675 (shelf 02/1 – 144C), height above floor 200 cm.

↑ RH/T records from Depository No. 3, sensor No. 07931674, height above floor 120 cm.

Specifications of the experiment under the NAKI programme

The experiment was carried out in Special Depository No. 3. Due to their character as combined material collection objects, the weapons stored there are in an inappropriate environment, threatened by high humidity and thus mould.

A simple building alteration could improve the indoor environment so that it is not necessary to install energy intensive air-conditioning systems.

The space was subjected to a microbiological survey due to the occurrence of fibrous fungi. Fibrous fungi or mould occur mainly on the surface of wooden parts of weapons and textiles or leather belts. Interestingly, mould was also discovered on metal parts of the weapons. The Depositary is permanently dehumidified due to the decrease in humidity, which naturally ranged above 65 % RV. This problem has been monitored for a long time and a microbiological survey was carried out in 2001. Samples were taken from the weapons and separate cultivations were carried out by exposing the cultivation soils directly in the depository. In 2015, the survey was repeated and the growths were evaluated at the Textile Testing Institute. Once more, growths were taken from wooden, leather, and metal parts of the weapons. Both surveys proved the presence of

Special depository for storing militaria. Source: Archive of the Technical Museum in Brno.

these moulds: *Penicilium sp., Aspergilus sp., and Chaetomium sp*[5]. These types of fibrous fungi are often found in interiors, soil, or on objects. Their activity is dependent on the conditions in which spores occur. Its occurrence on the metallic parts of the weapons is probably caused by the application of a preservative that has formed a suitable substrate for mould development. The environment in the armoury area has been monitored since March 2013.

The aim of the experiment was to design simple building alterations at minimal financial cost that would lead to improvements in the current conditions. The alterations were self-made and implemented by the TMB Operations Department in collaboration with professionals in the given professions.

THE EXPERIMENT WAS DIVIDED INTO THE FOLLOWING STEPS:

- Evaluation of RH/T measurements carried out, all year round
- Study of mould growths
- Design of building vents to improve airflow
- Proposal of changes to the layout of stored objects.
- Proposal of a more suitable rack system for the given collection items
- Recommendation of RV/T limits for the given combined collection objects/ weapons – leather, wood, metal
- Assessment of the experiment

Experiment

Adjustment of the microclimate in the weapons depository was to solve the poor, long-term relative humidity conditions.

Based on the proposal, simple and low-cost building alterations were made and the experiment was assessed after a year-long monitoring cycle. After evaluating the indoor climate, two new vents were placed to optimize the air flow throughout the depository area. To provide increased air circulation, an axial fan was employed from the SOLER A PALAU ELECTRODESIGN RM 150 line with an output power of 95 W. The air exhaust was placed in the original, unused chimney. An expert company inspected the internal and external con-

5 RNDr. Lubomír Schánĕl.

ditions of the flue route and created a new branch for our purposes. Two holes with a diameter of 130 mm were cut in the peripheral masonry of Depository No. 3. One hole was at ceiling height and the other near the floor. An air duct was connected to the upper opening and an axial fan was installed 4500 mm from the pipe inlet. It is controlled by a timer and is set to ventilate twice every 24 hours. The volume of exchanged air is 92 m[3]. With an air flow of 750 l/h, a minimum operation time of 15 to 20 minutes per 24 hours is required. The minimum operation time was distributed evenly throughout the day. During inactivity, a slight draught in the pipeline can be observed due to the natural chimney draught. The lower opening was fitted with a metal grille to meet the safety criteria of the Weapons and Ammunition Act.

Assessment

This simple and cost-effective adaptation brought about a significant improvement in the conditions of the indoor environment and based on visual monitoring, eliminated the development of mould on combined items, especially on leather. Therefore, time-consuming and regular application of disinfectants and preservatives that can form a suitable substrate for mould is unnecessary. However, as the suction opening is in Depository No. 2, no significant changes in the temperature and relative humidity of the flowing air could be achieved, and the values roughly corresponded with the Depository No. 2 graphs.

RH/T records from Special Depository No. 3, sensor No. 07931674, while the experiment was monitored (after removing the dehumidifier)

It is clear from the graphs that the measures taken did not compensate for fluctuations in temperature and relative humidity values. After removing the dehumidifier, RH values slightly increased within acceptable limits, as can be seen from Fig. 3. In summer, RH achieves acceptable boundary values. A positive outcome of the experiment can be seen in the improvement of overall air exchange and mainly in its directed flow. Increased air circulation prevented the development of mould in the deposited militaria.

With a 95 W rated output on the axial fan, operating costs for forced ventilation do not exceed 100 CZK/year. The experiment has demonstrated that inexpensive solutions to improve the indoor climate in premises for preserving cultural objects can be found. Each improvement in the environment leads to an improvement in the condition of the preserved collections and ensures the long-term and sustainable conditions for storing cultural objects. Designing a more appropriate storage system and long-term monitoring was no longer topical due to a change in location.

At the time of this text's publication, the depository is already empty and these objects have been relocated to a new depository (Fig. 4) that meets all the requirements for optimal storage, both in terms of indoor environment quality and protection and security.

The new depository in Brno – Řečkovice. Source: Archive of the Technical Museum in Brno.

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Reduction of relative humidity using a controlled conservation heating method

ALENA SELUCKÁ, PETR JAKUBEC

Summary

This study contains an analysis of the results of verifying a method for regulating high relative humidity in interiors by heating controlled with a humidistat. This method, known as conservation heating, was tested in the premises of a historical building. Microclimatic conditions were compared between an experimental room and a reference room with an uncontrolled environment. Changes in relative humidity and air temperature were monitored in different modes related to system characteristics for winter and summer months. The consumption of electricity for heating was also recorded, supplemented by simulation software analysis. The benefits and risks of applying a conservation heating method in a real structure's conditions are examined.

Introduction

One of the requirements for protecting objects of a cultural nature is to provide suitable indoor climatic conditions in areas designated for long-term storage. This area of preventive care is a set of monitoring precautions for memory institutions that regulate, evaluate, and record environmental parameter values, including relative humidity (RH) and air temperature (T). Although these physical values have to be considered together, because changes in temperature also cause changes in relative humidity, in terms of the risk of damage to sensitive organic materials attention is mainly paid to optimizing the ambient moisture conditions in the environment either in the building's interior or inside storage systems (showcases, cabinets, boxes, etc.). Relative humidity control options include measures concerning temperature change, air exchange, dehumidification, or humidification. For the purposes of the project called "Methodology for preserving cultural objects – optimizing conditions to achieve long-term sustainability", the controlled heating / tempering method was tested, which offers a relatively simple procedure for keeping humidity within acceptable limits. The study's aim was to evaluate this system in local climatic conditions in the context of conservation of materials as well as energy used for this method of operation.

Dependence of the condition of materials on the ambient air's humidity

Items made of wood, textiles, paper, leather, and other organic materials react to changes in relative humidity by absorbing moisture from the surrounding environment. At the same time, these materials have the ability to gradually adapt to ambient conditions when the diffusion equilibrium between the natural water content inside the material and its surroundings (equilibrium moisture content – w) is reached. However, if the ambient humidity is too high, too low, or it fluctuates, organic material reacts by changing its physical parameters as far as to the stage of damage (corrugation, drying out, cracking, etc.). RH values in the range of 40 to 60 % and T 15 to 25 °C are generally considered acceptable conditions.[1] This recommendation is based on the form of sorption isotherms which indicate the dependence of the equilibrium moisture content of the material on ambient relative humidity and air temperature. It is clear from the shape of the sorption isotherm of wood (Fig. 1) that RH fluctuations in the range of 40 to 60 % produce smaller changes in the equilibrium moisture content than at values above 75 % or below 30 %. Although the shapes of the sorption isotherms may differ, they are very similar for a group of materials such as wood, paper, and textiles. These materials can be damaged due to unsuitable ambient humidity by various mechanisms – hydrolytic decomposition of cellulose, dimensional changes caused by swelling and shrinkage, biological attack, increased activity of chemicals, etc. Of course, many inorganic materials are also sensitive to the surrounding RH with the risk of metal corrosion, or salt migration in ceramics, stone, glass, etc.

1 Organic hygroscopic materials can be acclimated to different microclimatic conditions, for example, exhibits stored in historical castles, chateaus, or churches with RH far higher than 60 %. In these cases, it is advisable to respect the original climatic parameters and not subject objects to changes beyond the historically proven range (even if there are acceptable conditions described above). This, of course, applies to cases when it has been proved that the objects are stable under the original conditions and do not show signs of damage; ČSN EN 15757. *Protection of cultural heritage – Temperature and relative humidity requirements to avoid mechanical damage to organic hygroscopic materials as a reaction to certain climates.* Office for Standardization, Metrology, and State Testing, 2011.

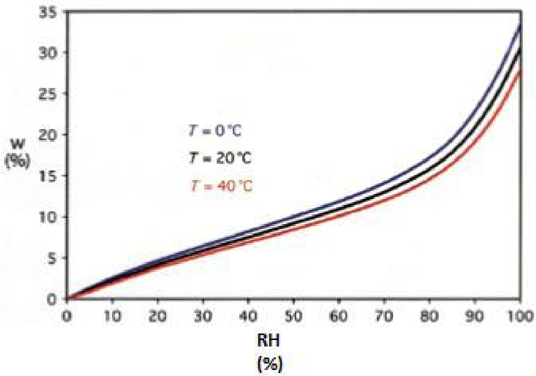


Fig. 1: Sorption isotherms of wood at different temperatures (w – equilibrium moisture content in wood, RH – relative humidity), adjusted according to Camuffo, 2014, pp. 84. It is clear from the sorption isotherms that the moisture equilibrium of the material also depends on the ambient humid air temperature.[2]

Moisture control inside buildings

Ensuring appropriate climatic parameters is crucial for preserving cultural objects in good condition and prolonging their life. The possibility to regulate the relative humidity in a building's interior is closely related to the building's characteristics, its location, the orientation of the building towards the cardinal directions, and the dislocation of rooms inside, etc. If the building itself does not provide stable climatic conditions and a minimum fluctuation of RH and T are required, the installation of air-conditioning equipment (HVAC) allowing different levels of heating, cooling, humidification, and dehumidification may be necessary. Their acquisition costs though are high and are usually installed during a new building's construction or more extensive renovations. In this context, a significant increase in energy consumption to operate these facilities can also be anticipated.

However, many objects of cultural heritage are kept in different types of building – existing buildings without HVAC, historical buildings, buildings protected as monuments, seasonal structures, etc. These are mostly objects characterized by a cooler and damper interior environment. In these cases, it is

2 Indeed, a hysteresis loop of adsorption and desorption of sorption isotherms is formed.

usually not possible to consider implementing modern technological systems with respect to the nature of the given structures. The solution for regulating microclimatic conditions must therefore be found by different means – consistent removal of poor conditions (such as water leakage, poor tightness of window fillers), using original air ventilation elements, airing, suitable protection of the building during winter, etc. [Červenák–Vácha, 2015]. Simple options for keeping the RH of air within acceptable limits include controlled heating (or tempering) or installation of portable dehumidifiers and humidifiers. Portable devices for limiting RH fluctuation are generally well-known in memory institutions, although tempering functions or heating for moisture control are less common.

Controlled increase in temperature leads to reduced RH of the air in the controlled air volume. Conversely, lowering temperature increases the relative humidity. The *conservation heating* method uses this principle and was the subject of the test in this study.[3] A high RH is avoided by heating or tempering, which is controlled by a humidistat (humidity controller). This procedure is particularly suitable for buildings with long-term, higher RH values, where very limited air control options are available using modern air-handling equipment and air-conditioning units. The concept of this method is primarily based on protecting stored materials and does not monitor the thermal comfort of employees or visitors.[4]

3 The conservation heating method has been introduced into many historical buildings managed by The National Trust in the UK; BLADES, N., POUPARD, S. and BARBER, L. Analysing the energy consumption of conservation heating system at the National Trust. *Journal of the Institute of Conservation.* 2011, vol. 34, No. 1, pp. 16–27. ISSN 1945-5224; BULLOCK, L. Environmental Control in National Trust Properties. *Journal of Architectural Conservation.* 2009, March, pp. 83–97. ISSN 1355-6207. It was also tested for the purposes of protecting cultural heritage in the Netherlands; NEUHAUS, E. and SCHELLEN, H. L. Conservation Heating to control Relative Humidity and create Museum Indoor Conditions in a Monumental Building. In: *Proceedings of the 27th AIVC Conference, Lyon France, 20–22 November 2006.* Lyon: 2007, pp. 45–50. ISBN 2-86834-122-5. As far as we know, this system has not yet been tested in the Czech Republic.

4 The term *conservation heating* means a method of heating that considers the conservation criteria for the preservation of stored materials.

Testing the conservation heating method

Experimental verification aimed at determining the effectiveness of the conservation heating system in local climatic conditions. The Lower Chateau Kunštát premises at Kunštát State Castle were chosen for the experiment (Fig. 2). It is a listed historical building and was adapted to the storage of archival materials in the 1960s. Currently, the structure is not used and its next renovation is planned as a repository. Two rooms (No. 117 – *Reference,* and No. 118 – *Experimental*) were selected, located on the second floor of the north wing of the building (Fig. 3). These areas have not been tempered in recent years and have exhibited a higher long-term RH of about 70 %. Both rooms were equipped with the same number and type of RH / T sensors for the experiment. The temperature and relative humidity parameters of the outdoor environment were measured by a sensor located at the window of room 117 on the northern wall of the building. All windows in rooms 117 and 118 were closed. The rooms connected via door openings (no doors installed), which were sealed with polystyrene boards 50 mm thick so that room 118 could not be influenced by the microclimate in reference room No. 117 or the environment in the other adjacent parts of the chateau itself. An MS6D data logger was used as the central unit for controlling, collecting, and recording data into memory, together with a relay card for switching the heating on. Heating was provided by two oil radiators with output power adjustable to 600, 900, or 1500 W. Total energy consumption was also measured by a special device located outside the monitored room.

↑ *Fig. 2: Kunštát Lower Chateau, National Heritage Institute. On the right is the north wing of the building where the conservation heating experiment took place on the second floor. Photo©Technical Museum in Brno.*

↑ *Fig. 3: Experimental room 118 at the Kunštát Lower Chateau. Door openings were sealed with polystyrene board. Photo©Technical Museum in Brno.*

Two modes were set for the experiment's operating conditions to switch the radiators on (ON) and off (OFF):

1. EXPERIMENT BETWEEN JUNE 2013 AND DECEMBER 2014

Two oil radiators were connected to the control system, both being set to the lowest output power of 600 W (i.e., a total switched output power of 1200 W).

MODE A1 ON

If the RH (in room 118) is higher than 59% ± 2% and
the T (in room 118) is lower than 22 °C ± 0.1 °C

MODE A2 OFF

If the RH falls below 57 % (T is not considered)

MODE B1 ON

Always if the T falls below 5 °C (RH is not considered)

MODE B2 OFF

If the T is higher than 22 °C (RH is not considered).

The results for the first period of the experiment showed that with humidistat controlled heating an acceptable relative humidity value of below 60 % was maintained for almost the whole of 2014. During summer (July–August), when the internal temperature exceeded 2 °C, the system switched off and RH increased to about 65 %. However, this RH variation in the range of ±5 % of the upper set limit does not in practice pose a greater risk to stored materials and may be eliminated by additional dehumidifiers. The total electricity consumption for heating was 7.211 MWh over the given period of one year. According to the experimental room's volume of about 129 m^3 (the volume of air to be heated), energy consumption was 56 kWh/m^3.

The study was also supplemented with a simulation analysis[5] of electricity consumption for heating under different external climatic conditions, supported

5 In cooperation with the Brno University of Technology's Faculty of Civil Engineering and AdMaS Center, the Danish simulation tool BSim used for thermal humidity analysis, simulation of indoor environment parameters, and building energy balances, etc. MAUREROVÁ, Lenka. *The conservation heating experiment in Kunštát Lower Chateau.* Case study – Simulation of the course of selected parameters of an internal microclimate for variation of the boundary conditions to calculate different climatic data and heating regimes, a partial report on the project called "Methodology for preserving cultural objects – optimizing conditions to achieve long-term sustainability". Brno: Archive of the Technical Museum in Brno, 2015.

by reference data from different meteorological stations (Brno – Tuřany, Copenhagen, Kiruna). In the case of data processing of the reference year[6] from the Brno-Tuřany station (average annual outdoor values T_{ext} 9.8 °C, RH_{ext} 76.6 %), a comparable power consumption as in the case of real data obtained during the experiment was confirmed. In the colder and damper climate of Copenhagen (T_{ext} 7.8 °C, RH_{ext} 82.7 %), it would be necessary to increase heating capacity to 3 kW in the winter months to keep the lower temperature limit of 5 °C. This would be equivalent to a 23% increase in heating energy consumption. The very cold and somewhat drier climate of Kiruna (T_{ext}. -1.1 °C, RH_{ext} 74.4 %) would represent a significant increase in heating capacity to 4.2 kW and the need to humidify the space in winter with an overall increase in energy consumption of 231 % compared to the real consumption measured in 2014. In this case, the conservation heating system will no longer perform its function. Interesting results were also obtained from simulations of the indoor environment control within the required RH and T limits using a hypothetical air-conditioning unit located in the experimental room – electricity consumption would increase by 29 % compared to the costs of the conservation heating system. Detailed results of this study were published in SELUCKÁ, A. – JAKUBEC, P. – MAUEROVÁ, L. – HIRŠ, J., 2016.

2. EXPERIMENT BETWEEN MARCH 2016 AND APRIL 2017

The aim of the second operating mode was to test the system when the upper permissible RH threshold was raised to 65 %. The reason was to discover the behaviour of the system and its related electricity consumption for heating at the given parameters, which may more closely resemble the climatic conditions some objects have acclimated to in the long term. Lower power consumption was also expected under this setting.

Two oil radiators were connected to the control system, both being set to the lowest output power of 600 W (i.e., a total switched heating capacity of 1200 W). Due to the condition of the 230 V power line (10 A fuse) and therefore the risk of a power outage for the whole experiment, it was not possible to increase the heating capacity.

6 The reference year means the average of the climatic data obtained from measurements during the multi-year time period (about 30 years) at the respective location.

MODE A1 ON

If the RH (in room 118) is higher than 65 % ± 1% and
the T (in room 118) is lower than 22 °C ± 0.1 °C

MODE A2 OFF

If the RH falls below 64 % (T is not considered)

MODE B1 ON

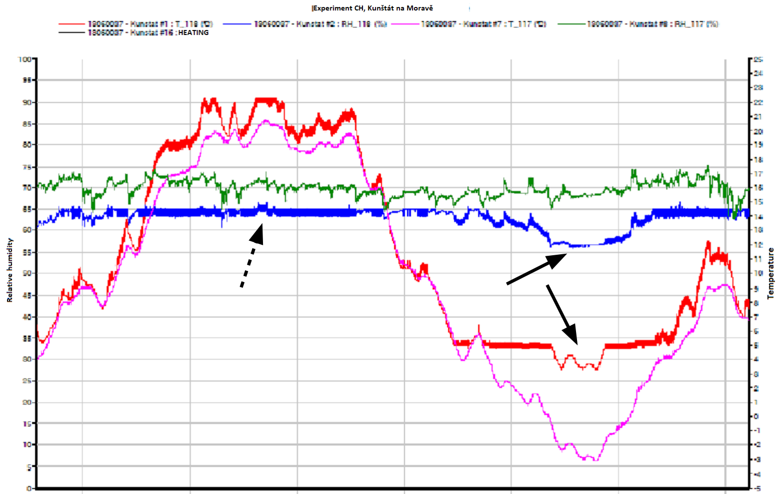
Always if the T falls below 5 °C (RH is not considered)

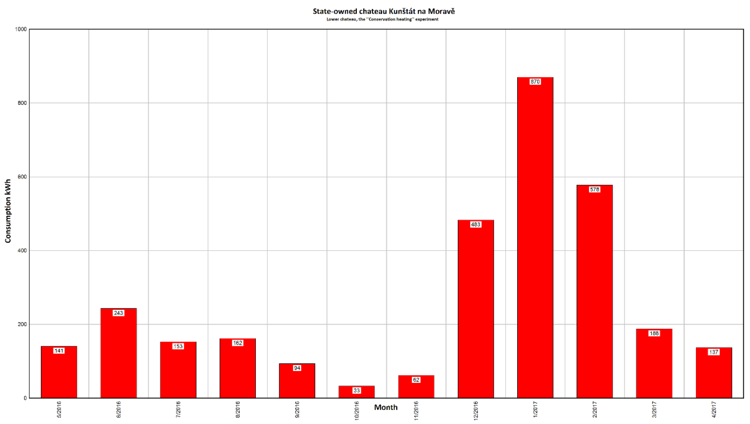
MODE B2 OFF

If the T is higher than 22 °C (RH is not considered).

Measurement of RH/T parameters during the experiment is documented in Fig. 4. The RH in the reference room 117, fluctuates around 70 % during the monitored period (RH_117, green curve). Using controlled heating in experimental room No. 118, RH reduction to 65 % ± 1% is achieved almost throughout the entire measurement period (RH_118, blue curve). Significant drops in moisture RH_118 below 65 % occur only in winter when the temperature in the reference room drops to 5 °C (T_117, pink curve). Initially, the lower temperature limit in the experimental room was maintained at 5 °C (T_118, red curve), although it already meant a reduction in RH_118 below 65 %. When the unheated room is significantly cooled to as low as below freezing temperatures, the output of the heating elements (1.2 kW) is not sufficient to maintain the T_118 value at 5 °C (marked with continuous arrows on the graph), but the actual drop of RH_118 is not so significant. In the case of increased heating output, RH_118 reduction would probably be more significant at about 50 %.

The opposite situation occurs in the summer months when the upper limit T_118 of 22 °C is achieved and the heating elements switch off and a slight increase of RH_118 above 65 % (marked with a broken arrow in the graph) occurs. Total electricity consumption for the period 01.05.2016 to 28. 04. 2017 was approximately 3.15 MWh. The monthly consumption is shown in Fig. 5 and external climatic conditions are shown in Fig. 6.





↑ *Fig. 4: Measurement from March 2016 to April 2017 of RH and T parameters in the reference and experimental rooms, including the heating units switching on and off.*

↑ *Fig. 5: Monthly electricity consumption (May 2016 to April 2017).*

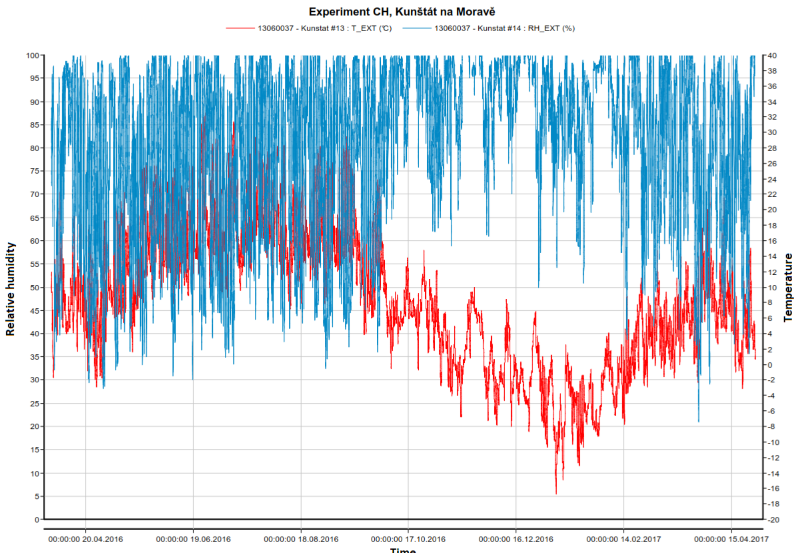


Fig. 6: External temperature and relative humidity (May 2016 to April 2017).

Discussion of results

Testing the *conservation heating* method under these two operating modes confirmed a simple way of regulating relative humidity with humidistat controlled heating. The relative humidity value in the experimental room was kept below the set upper limit for almost the entire measurement period. Only in winter when a significant drop in external temperature below 0 °C occurs is it necessary to increase heating capacity to achieve the lower temperature limit of the interior of 5 °C. At the same time, the relative humidity of the interior may fall below a certain limit under these conditions, so local humidification must also be considered. A special aspect of this system is the need to heat the room during summer to maintain desired RH values. In this context, an upper temperature limit of 22 °C was chosen. When this limit was exceeded, the heater always switched off and a slight increase in RH of about +2 % to 5 % occurred, which in conservative terms does not represent a significant fluctuation that endangers the stability of materials. In the case of the second experiment's mode settings, RH exceeded 65 %. Although this was a slight fluctuation of + 2 %, this upper limit of RH can already be considered an increased risk for mould growth and corrosion of metallic materials.

The method's concept is based on the preference of regulating humidity conditions and allowing greater fluctuations in temperature. In this respect, they are seasonal and gradual temperature changes which respect the permissible lower and upper values (i.e., T_{min} 5 °C and T_{max} 22 °C). Accelerated chemical reactions due to higher temperatures (e.g., hydrolytic decomposition of cellulose) does not pose a more significant problem. In real situations, however, attention must be paid to checking the condition of objects when moving them from cooler spaces to tempered or heated rooms (even if the ambient relative humidity is the same), as surface dew and subsequent mould development may occur.

The main aspect of the efficiency of the system is the cost of heating energy consumption. During the first phase of the experiment (2013–2014), the real value of consumption was 7.2 MWh, which is 56 kWh/m^3 after conversion to the space's volume. The second part of the measurement with the newly set operating conditions (RH limit of 65 %) corresponds to a lower electricity consumption of 3.15 MWh (2016–2017), which is about 24 kWh/m^3 after conversion to the space's volume. By setting a higher RH limit value, significantly lower electricity consumption and thereby cost was achieved. Temperatures in both rooms (experimental and reference) were very similar for a part of the year (especially spring and then autumn 2016), which meant no increase in the experimental room's temperature during this period was needed to reduce its relative humidity. However, the higher upper limit of the RH value and associated reduction in energy consumption must be assessed in the context of possible risk of damage to the stored materials.

Conclusion

The functionality of the *conservation heating* system will in practice be greatly influenced by a building's characteristics, the building's envelope, its spatial fragmentation, air infiltration, and the like. The demands on heating output may also increase in a leaking or poorly insulated building. In relation to interconnected and complex spaces, the conditions for non-uniform distribution of temperature and humidity can thus be created.[7] In terms of the spaces tested in this study, these are separate rooms intended to serve as separate repositories in the future. If HVAC installation is not considered and the facility is equipped for permanent (or temporary) heating / tempering, humidistat-aided regulation is a simple alternative for optimizing indoor conditions. This system may be considered against the use of dehumidifiers whose operation may in some cases be more energy-efficient, but have other complications associated with their limited operation at lower temperatures (generally below 8 °C) and the operational problems of draining water from their tanks. From the point of view of predicting the cost of energy consumption per air-conditioning unit providing the required microclimate parameters in a given test space, energy costs by a third higher were calculated compared to humidistat control. The effectiveness of optimizing humidity conditions in premises serving for the long-term storage of cultural objects will in practice depend on the type and performance of heating elements used. Some other studies show that humidistat

7 This aspect was brought to attention by an article review MAUEROVÁ, L., SELUCKÁ, A., JAKUBEC, PP. and HIRŠ, J. Implementation of simulation analysis in verification of heating efficiency using the method of conservation heating in a historical building. In: *Heating, ventilation, installation.* 5/2017, p. 278, in print.

heating is energy-efficient when applied in combination with heat pumps.[8] In this context, it is also worth pointing out that any heating or other electrical equipment increases fire risk and should therefore be used in combination with automatic shut-off safety devices in the event of a failure.

Acknowledgments

The authors would like to thank Bc. Radim Štěpán from the Kunštát State Chateau's administration under the National Heritage Institute and the Territorial Monument Administration in Kroměříž for their cooperation in this experiment.

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Historical Heating Systems and Visitor Traffic at Listed

Buildings with Public Access

JAN ČERVENÁK, VÁCLAV HOLÁSEK

Abstract

This article provides an overview of the history of heating systems in our listed historic buildings and the characteristics of particular types, from open fire pits and furnaces, mainly seen as so-called *black kitchens*, to fireplaces and various heating stoves. The authors also examine systems that were devised in antiquity – the direct flue gas type (hypocaustum). They include an overview of so-called *cannon stoves* and describe how these systems function. Increased efficiency for warm-air systems was achieved with flue-way calorifiers, which have been replaced by modern central heating systems. These systems, which were most often gravitational, were mostly built with radiators thanks to their simple operation.

The authors also draw attention to the risks associated with heating systems no longer in operation and the need for proper maintenance and inspection, just as with operational systems. Finally, the relationship between these systems, visitor traffic, and the regulation of microclimate in spaces intended for storing cultural objects is discussed.

Radiator, period publication.
Photo: Author's archive.

The theme of historical heating systems in accessible listed buildings is very broad and extensive for one paper, so the aims in this chapter can only be partially achieved. For most buildings, no universal manual can be created or decisive factor determined involving this special field. It is especially because the factors and methodologies for this field are difficult to present in such a way that they won't be misinterpreted and misused and cause damage to historical buildings.

For example, different climates in places where even the same builder often built can be crucial. The climate in our country, such as in Mikulov, is different from that in Horská Kvilda, and a difference exists between the average climate values in Czech lands and, say, France. Another aspect is the purpose for which the structure was built; a fact often neglected. Many historical buildings are now used for completely different purposes than originally intended by their architects. Only few buildings were built as museums, and the architects of the castles and chateaux certainly did not assume that exhibitions would be established in these buildings centuries after their existence.

Changes in building occupancy led to demands for different climatic parameters. Interventions or measures to optimize the environment for cultural objects should therefore not be carried out without a proper and thorough survey of the site, including its surroundings.

A brief insight into the development of heating

People have been using fire perhaps since they were able to hold tools in their hands. Even then, people began a long journey of learning to maintain fire in a section of their dwelling where it served a benefit and did not damage. If, for example, they managed to settle in a cave with a chimney created by natural geological processes, the solution was easy. However, when forced to look for an alternative self-constructed shelter, it was a challenge.

OPEN FIRE PITS AND FURNACES

Open fires transmitted the thermal energy contained in fuel, mainly wood, by radiating directly into the surrounding space. Dishes were prepared on the fire, clothes were dried over it, etc. They were mainly clay furnaces that used heat better, such as for cooking or pottery making, and later for working with metals. They were often built outside under a separate shelter. Flue gas was exhausted via a simple chimney hood, later a chimney. In prehistoric and ancient structures, a bulky stone served as the fireplace's base and a hole in the wall or roof as a chimney hood. Building an elevated fire pit in a separate room with a chimney or a chimney hood gave rise to the so-called *black kitchen*, which can be seen in historical buildings even today. Regular inspection and maintenance of the flue duct was in this case important for the structure's condition.

FIREPLACES

Fireplaces are used for similar purposes. The general idea of medieval resident life in castles, for example, leads to the notion where people crouched by the fireplace and felt hot in the face, but cold on their backs. While it may have been true when an excessively cool room was heated, when the room was heated over a longer period the walls of the room (often constructed with wooden insulating) warmed and the perceived ambient temperature became quite acceptable. However, the thermal efficiency of open fireplaces is fundamentally very low (up to 7%). With certain variants of this heater, especially in modern ones, we can see models with an additional air intake duct and control flaps for combustion. These are other important components of the heating systems requiring systematic control and therefore maintenance.

Another, less-known thermal equipment is the so-called *lighting fireplace*. They can be seen in stables, sheds, and farmhouses generally or hospitals. Many variations in size and technical specifications exist. Flue gas is usually exhausted through a chimney or simple chimney hood. To date, information has been published that these devices served primarily for illumination due to the small dimensions of the opening to the combustion chamber (e.g., 30 to 40 cm, which also provides the firewood dimensions). In many rooms with these fireplaces, however, metal grips for pine torches and lanterns can be found, which is why lighting was not the only reason these facilities were built. A fireplace of this capacity could affect air flow in the building and move the temperature above the dew point and thus reduce water condensation. If such a heat source is located, for example, in a workshop, it would be enough for a slight increase in temperature, even if room temperature is not required in workshops.

STOVES

The development of building types and techniques led to improvements and increased efficiency in heaters. Thin ceramic tiles were used for better transfer of heat from the fire place into the heated space (and its accumulation), which gave rise to the tiled stove. In each historical period, the tiled stove was improved in at least one technical detail. Baroque stoves already had a forged basket inserted around the inner hearth that prevented breakage of the thin ceramic wall by wooden logs when stoking. The stove with service holes outside the heated room probably comes from the Renaissance period. It reduced the amount of smoke and ash, improving the living comfort. Tiled stoves achieved even more remarkable accumulation properties with full lining and a flue duct system in about the middle of the nineteenth century. A good example of this is the development of the domestic bread oven, which can still be found functional in many farm kitchens. The heat generated while preparing dishes heated the accumulation mass of the oven and often radiated heat until the next fire lighting, thus reducing the demands on its operation. This development continued with more technical improvements, and brings us to the next chapter.

STOVES AND KITCHEN EQUIPMENT

Although fuel was partially saved thanks to various modifications to heaters, many fireplaces and black kitchens were still used for preparing food in the nineteenth century, not only in the countryside. After developments in metallurgy and mining, coal gradually started being used as a fuel. For cities often heavily burdened with exhaust gases, important progress was made with improved kitchen heaters called stoves (the Czech word *sporák* is based on the German *Sparherd*, loosely translated as an *economical fireplace*). The efficiency of heating energy transmission increased noticeably. While a small hearth heated up a steel or cast-iron stovetop, flue gas flowing through the cooker body heated the tin oven and often also a hot water tank, which significantly increased the efficiency of the heat energy transfer in kitchens in large feudal residences. Even restaurants, military barracks, etc. were equipped with stoves with a number of ovens or hayboxes. New confectionery ovens were also used.

The need to obtain maximum energy usage from fuel led to even more technical improvements. Improved metal processing technologies allowed more affordable material which is still ideal for heaters due to good thermal conductivity facilitating better heat transfer efficiency. Many variations of metal stoves, stoves, and other heaters can therefore be encountered. Economical solutions lead to the idea of heating multiple rooms with one hearth, which is the subject of the next chapter:

The history of heating systems

If we want to at least partially learn about the development of these devices, it is important to understand their principles and return to ancient Rome, where the first direct flue gas heating system may be encountered. According to written records, it was called *hypocaustum*. It was similar to today's underfloor heating. Flue gases were funnelled through a system of channels into the cavities below the floor so that the floor and even sanitary water were heated. A typical example where this method of heating was used was the spa. Ruins of these systems from ancient times can also be found in our territories in medieval castles and monasteries (in 2002, the heat from similar facilities in public spas from the turn of the nineteenth and twentieth centuries in Syrian cities such as Damascus or Aleppo could be used).

Hypocaustum – a view of the floor construction heated with flue gas. Photo: Cejpová, Miroslava. Fireplaces preserved in castle kitchens. In: *Proceedings 1/2003, Proceedings from 1st Conference on Construction and Historical Survey 4–6th June 2002 at the Zahrádky u České Lípy chateau*. Prague: Unicornis, 2003. ISBN: 80-86562-00-X.

Direct *flue gas heating* was used later, for example, to heat orangeries and greenhouses. In many greenhouses numerous, almost usable systems can be found (e.g., near Veveří Castle, Telč Castle Park, and in the private garden in Lednice in Moravia, where the owner still uses this heating as a modern device to force seedlings).

The hot-air system was another method for heating orangeries and greenhouses. A stove assembled from tiles placed in the heating chamber under the structure heated the air flowing through the air diffuser into the heated space. The cooled air was brought back to the heater through an opening near the floor, resulting in gravitational circulation. It is therefore a circulatory system.

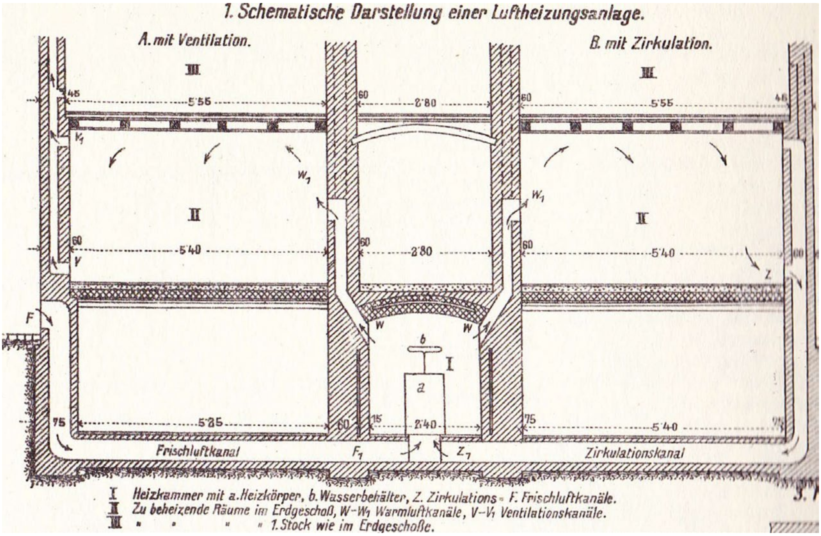
OUTLINE

At the beginning of the nineteenth century, a special commission was set up by the Supreme Command of the Austro-Hungarian Army to find an economical solution for heating military structures. It had to save resources, including human power, which could serve in the Napoleonic Wars in a better manner than preparing fuel. The stove appeared to be the most suitable heater according to a proposal originating in Russia. Its shape was reminiscent of a cannon's barrel turned to the ground, hence the name *Eiserner Kanonenofen* – iron stove. In other historical sources, they are known as the *Komárov* stove, such as those manufactured by the foundry in Komárov (near Brno).

The iron stove transmitted heat very well to the environment, hot air systems being more efficient, and led to their widespread use. In the middle of the 19th century, these systems were standard equipment for luxury residential buildings, but also in public buildings such as schools, courts, or hospitals.

In these buildings, however, the circulatory system was not entirely satisfactory. Many people were present during public building opening hours and air quickly became stale and the system only heated it up. For those cases, fresh air was supplied under the heater in the heating chamber. This created a system of ventilation by overpressure. Heated fresh air from outside rose in a heated room and expelled stale air through leaks in windows, doors, or through a venting channel, but it necessitated heating the building even outside its operating hours. Heating with a ventilation system when the air is not polluted, however, is very uneconomical. A combined system is formed by merging the principles of the two systems, enabling heating by circulating air outside opening hours and then re-setting the system into ventilation mode using the control elements during the operating time.

Iron stove in a heating chamber. Photo: V. Holásek.



A diagram of the hot-air systems, on the left with ventilation, on the right with circulation. Photo: Titscher, Franz. *Die Baukunde mit besonderer Berücksichtigung des Hochbaues und der einschlägigen Baugewerbe: Lehr-, Hilfs-, Nachschlagebuch und Konstruktionsbehelf für Baukundige*, Studierende, Gebäudeverwalter usw. 4., verm. und verb. Aufl. Wien: F. Titscher, 1919. xiv, 612 p.

At the turn of the twentieth century, even more efficient heaters for hot-air systems were devised, such as *kaloriferofen* (flue calorifiers), whose name sounds like "heater" in translations from the German documents of 1919. Today, this is a widely used term for an S-shaped heat exchanger, mostly for hot water, steam, or oil. In a direct flue gas calorifier, flue gas flows from the furnace through one or several calorifiers in the heating chamber. The heat exchanger surface area is much larger, and several smaller hot air systems can be replaced with one central system. The German term *zentralheizung*, translated as *central heating*, can be found in sources from the early twentieth century. We mostly associate this term with hot-water radiators, which are discussed below. The literally translated term *zentralheizung*, namely, central heating, is currently used for large systems where more boiler rooms or heaters are replaced by one, central source such as a heating plant, power plant, etc.

Since around the middle of the nineteenth century, central heating systems have been popular, using not only air, but also steam or hot water as a medium for transmitting thermal energy. The medium is heated with the heat from fuel combustion in the boiler (source) and it circulates gravitationally between the source and the heat exchanger (calorifier) or radiator in the heated room. Many decorative variations of these heaters can be found, indicating the desire for their decorative application. However, their placement in a heated room is not always appropriate. In representative rooms the aesthetic aspect was at least as important as heating, and due to their convenience and economy of operation, a revival of, for example, tiled stoves could not be considered. The solution was to combine the systems.

It was enough to place radiators supplied with heat from the boiler into the heating chamber, creating a *steam-air system*. The building acquired all the benefits of both systems by installing such a system. Fuel is transported to only one boiler room (operation is less demanding) while all the advantages of the gravity function of a hot-air system can be applied at the same time.

Over time, central heating with radiators became popular. The *gravity system* was most often installed for its easy operation where the heating medium, either steam or water, circulated through the system based on only a thermal gradient. Its disadvantage was the need to adapt the system in terms of height, which could not be achieved in every building. A *hot water system* including a pump was created, and *forced circulation* was achieved. Because such systems could be installed almost anywhere and no need existed to specially adjust downhill pipe routes, it became so popular that most contemporary experts on this issue do not even know other systems and promote only this type hot water system.

A system of sewers, channels, drainage, and ventilation ducts has been built in the past around many buildings to maintain the water regime in and around the building. A desired humidity value was achieved by this, excess water being discharged and thus sometimes even supplied. The importance of controlling the indoor environment with the systems mentioned above and their importance for the overall energy balance of buildings are still unknown or at least underestimated for monument managers, and even for designers.

Current situation

We almost always encounter heating systems in historical buildings, especially public buildings and private dwellings, but they are often in poor technical condition. The biggest devastation for them is not a lack of maintenance, but rather amateur interventions during repairs or modifications. All the above-mentioned heater types inside buildings needed *chimney systems* for their operation. Since most chimneys are currently not used for discharging products of combustion, they are adapted to utilities or ventilation. Those that are still authentic are not regularly checked or maintained. The passages are full of soot, ash, rubble and often even droppings and the bodies of dead animals. Broken chimney hoods and heads permit ingress of rainwater, which causes moistening of the substrate resulting in a favourable environment for a wide range of harmful biological pests. In hot-air systems, *channels and vents* are preserved in most cases. However, as with unused flue pipes, they are often in poor condition today, often damaged by cable routing, which reduces flow and makes proper maintenance difficult.

Deactivated heaters, including local units, often contain a significant amount of ash and soot from the time it was last used. This is true even at locations where only surface appearance is maintained. The retained substrate, a nutrient broth for biological agents, maintains increased moisture, which particularly damages the metal parts of heaters.

Substrate in the hearth of a damaged iron stove. Photo: V. Holásek.

Sewers and related drainage or ventilation ducts are also damaged in many cases. Most damage is caused (often by current) unprofessional interventions and lack of maintenance. As a result, water from the sewer system penetrates the damaged ventilation system and thus provides a large amount of moisture for the interior.

As already mentioned, most buildings serve completely different purposes than what they were built for. Castles and chateaux in particular were originally intended (often seasonally) for housing and social events and are now effectively *exhibitions with visitor traffic*. For buildings where only around ten people visit per day, this traffic is positive for the indoor climate. Its regulation is ensured via the relevant personnel. However, we encounter the opposite when visitor traffic is extreme, which is harmful to the building. It is mainly the moisture that visitors leave behind in the building via sweating and exhalation that impacts negatively. It is difficult to determine an average ("optimal") value, because many factors affect the quality of the indoor environment under certain situations. These are the weather, the building's air flow, and the number of visitors in rooms. The highest humidity values with negative impact on the environment are achieved in sections where several dozen visitors walk through at regular interval and stop to listen to a guide's talk. Therefore, regulation of visitor numbers and a viewing regime is sometimes necessary (for example, at the Rotunda of St. Catherine in Znojmo).

Most of the factors adverse to the climate of historical buildings have been summarized, so a proposal for action can be proceeded to. Each building is special. Firstly, both the building's original and new purpose must be known. The condition of the building must be evaluated whether it allows the desired operation today without risk of damage to the construction or objects stored in it. Assessing the technical equipment, such as heating, the ventilation system, protective panelling, etc. is a no less important procedure. Then, an expert must determine the desired values for a (micro)climate to store furniture and other exhibits. It is important to consider whether these parameters can be achieved at all and depends on a long-term, systematic measurement of temperature and humidity. The location of sensors is individual and according to the layout of individual buildings and their layout, also affecting other measurements, such as carbon dioxide levels. A detailed construction and technical survey is needed, dealing with the broad context of construction work and its potential failures.

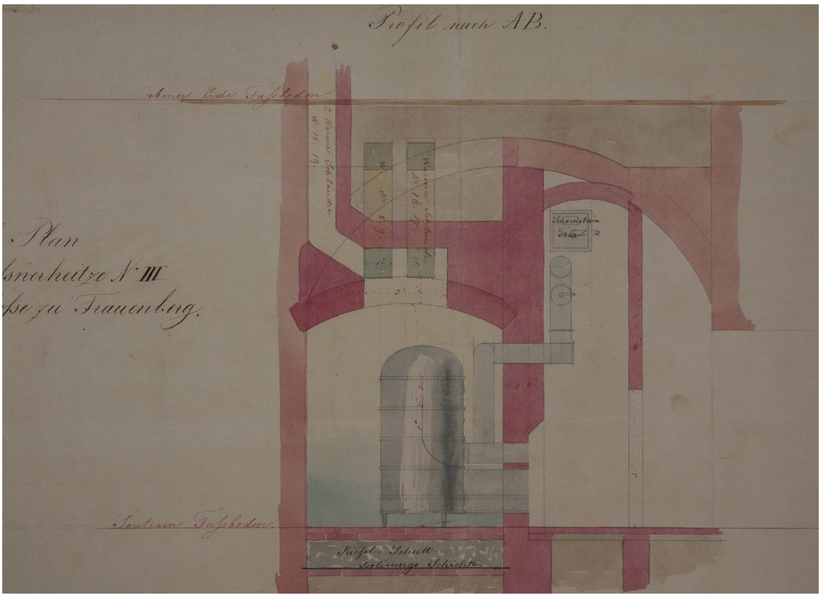
Only when the maximum relevant information is collected can anything be evaluated, although many criteria can only be determined with testing, especially the permissible visitor traffic. When determining the broader purpose of the structure, considering the influence of the visitor rate on the structure and exposed exhibits is necessary, but at the same time the visitor's comfort is also important. Air quality must be ensured so that it is not unpleasant or even dangerous to breathe, and does not cause, for example, fainting. It is well-known that a climate suitable for people may not be suitable for interiors and the exhibits housed there.

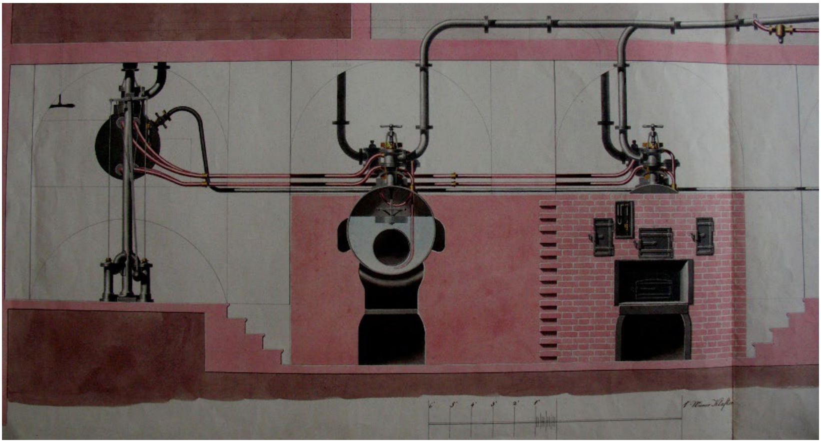
Similar criteria must be considered for *museums and galleries*. In these places, climate is not heavily burdened with the visitor rate, and exhibitions no longer have to be subjected to historical (value) limits, unlike historical buildings adapted to public access. Exhibits can also be stored to a greater extent in showcases, where they are mostly isolated from the visitor environment. A greater emphasis can therefore be placed on the audience's comfort.

Depositories, however, are spaces inherently different from those already mentioned. The climate in these places should have parameters determined by an expert (climatologist, conservator) for the different types of materials from which the artefacts are made. For example, wood requires a different climate to metals. The permanent presence of people, given the need for a stable environment, is clearly undesirable, unless it is a research depository. For new buildings built for this purpose, this problem is already solved in the project phase and the building is often equipped with HVAC systems. In buildings originally built for other purposes, especially castles and chateaux, using the original means and systems to adjust the climate is highly desirable. Ventilation, tempering, dehumidification, and humidification can in many instances be done using the original channels, vents, and chimneys. Careful consideration though should be given to any interference with historical building components whose significance, even in the case of environmental regulation, is irreplaceable.

If increased humidity is present in the interior, its cause must be found and removed. The *impetuous use of dehumidifiers and heaters* is undesirable as it can make the problems worse. Due to less moisture in a dried room, capillaries may expand and thus open the water path, supplying the environment with even more water. The use of dehumidifiers near open channels, vents or other potential sources of moisture has a similar effect, and not to mention is inefficient. Operating a heater in a damp room may result in moisture travelling to other parts of the building. It should also be borne in mind that severe drying can irretrievably damage many materials. Dryers should only be used after the cause of the dampness has been removed, such as sudden faults, floods, or similar, or after wet processes have ceased during construction works. It is also advisable that humidity be reduced during short-term climatic anomalies when the atmospheric humidity is higher than that required in the interior. In this case, incoming air must be prevented from entering dried areas and the appropriate part of the ventilation system or HVAC must be shut down and closed. Removing excess moisture brought into a room by visitors can also be done with a dryer. Everything should be carefully considered and it is necessary to ascertain whether the source of moisture is prevalent or an isolated case.

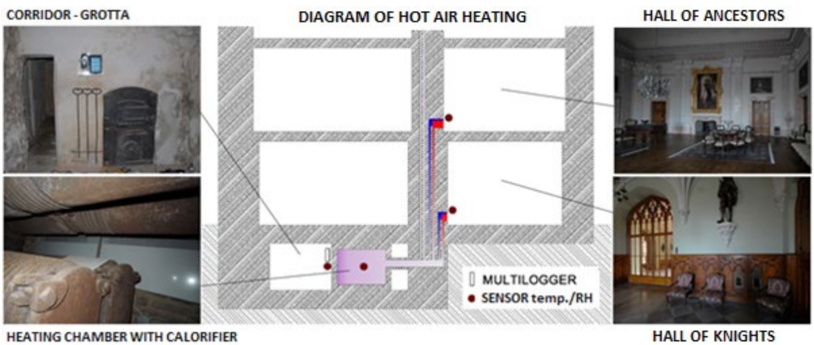
Design of iron stove in a heating chamber with channels for hot air distribution. Hluboká nad Vltavou Chateau. Photo: Author's archive.





↑ Design of boiler room with low pressure steam heating. Lednice Chateau. Author: Samuel Bollinger, around 1840. Photo: Authors.

↑ Area for operating a hot air heating system with a calorifier. The heating chamber is fitted with a revision door and water level indicator to control the water level in the evaporation vessel for humidifying the air. A control panel for the hearth is at the front part of the heater. Two channels for hot air distribution lead from the calorifier. Lednice Chateau. Photo: Authors.



↑ Controlling flap valves for individual heated rooms in the operator's area. Steel cables are missing. Hluboká nad Vltavou chateau. Photo: Authors.

↑ Diagram of hot air heating at the Lednice chateau. Photo: Authors.

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Preliminary Design for a New Depository of Works of Art from the Collections of the Moravian Gallery in Brno

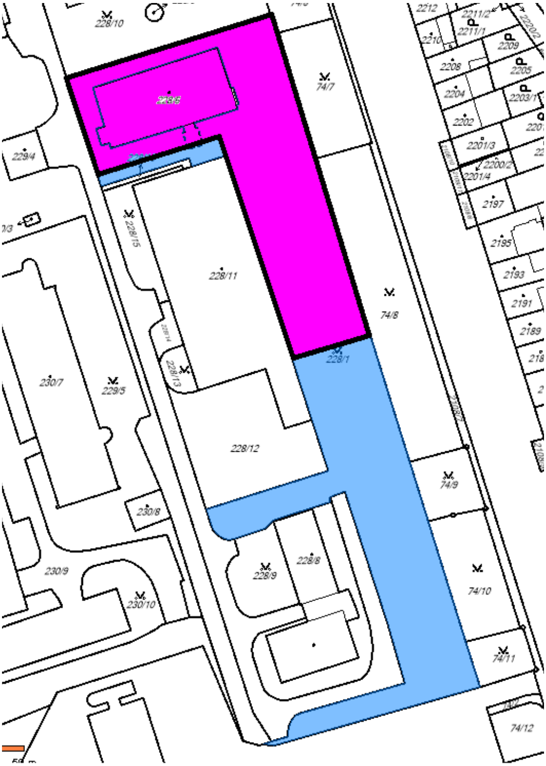
IGOR FOGAŠ

Long-term storage of collection objects, especially fine arts and applied arts works, is a highly specific and incredibly complex process in terms of implementation with regard to negative impacts of the immediate environment. Materials, the works of art are made of, age in the course of time due to various adverse effects despite sustained efforts to conserve and restore them. The effective means for preventing unnecessary decay and damage to the collections include optimum conditions for their storage and minimization of all risk factors on suitable depository premises. In consequence of the pursuit of new strategies of museums and galleries on the protection and presentation of objects of cultural significance, also opinions on the suitability of some structural designs and technical solutions for specialized depositories have changed. The conception of a new purpose-build building of average structural quality equipped with operationally extremely demanding air-processing systems has undoubtedly been challenged. From the perspective of current knowledge and experience the conception of a quality building with only limited support of effective and environmentally-friendly technologies and equipment seems to be a reasonable alternative.

The Moravian Gallery in Brno is the second largest art museum in the Czech Republic and is exceptional especially because of the wide range of collected objects. The gallery focuses on various types of fine and applied arts and has been pursuing a comprehensive approach to visual arts since its foundation in 1961. Owing to the fact that the storage rooms have been filled to capacity, the institution plans to build a new depository, connect it with the existing central depository completed in 2008, and include necessary landscaping (see figure below).

Preliminary design – a new depository of the Moravian Gallery in brno in the premises in Terezy Novákové street Brno-Řečkovice

CONSTRUCTION PROJECT AND SITE IDENTIFICATION



Lot numbers:	228/1 and 228/6
Community:	Brno [582786]
Cadastral territory:	Řečkovice [611646]
Ownership deed number:	6673
Area [m²]:	4547
Type of lot:	KN lot
Current use:	greenery
Type of plot of land	other area
	built-up area and courtyard

The area for the anticipated new building is located to the south-east of the existing main depository building

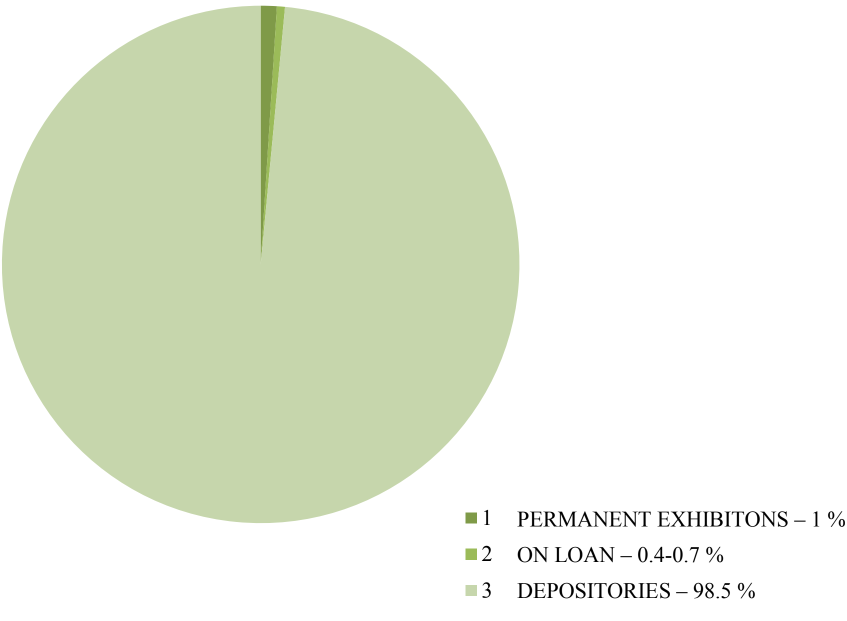
1. Pre-Investment Preparation

Initial State, Current Status Analysis

BRIEF DESCRIPTION OF THE CURRENT STATUS

The Moravian Gallery in Brno owns and administers a collection of more than 200,000 collected objects (individual items). The collection is displayed to the public in three permanent exhibitions in the buildings of the Applied Arts Museum (hereinafter abbreviated "AAM", Governor's Palace, and Pražák Palace. Part of the collection is on long-term and temporary loans and, therefore, displayed outside the institution. The majority of objects in the collection are stored in depositories of the Moravian Gallery in Brno.

PIE CHART OF THE LOCATION OF OBJECTS IN COLLECTIONS



It is apparent from the chart above that the majority of collected objects are stored in depositories of the Moravian Gallery in Brno.

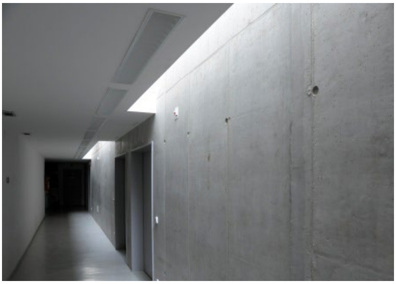
Depositories of the Moravian Gallery in Brno

CENTRAL DEPOSITORY OF THE MORAVIAN GALLERY IN BRNO

Address: Terezy Novákové 64a,
Brno-Řečkovice
GPS: 49°14′58.92″ N, 16°34′40.68″ E
Lot numbers: 228/11

The main depository of the Moravian Gallery in Brno was built from 2006–2008, the useful area in the depository rooms is total 2,157.7 m^2 and houses collections of fine and applied arts (the major part of applied arts collection is deposited in another building). The total number of objects stored is approximately 78,000 pcs (i.e. 40% of the entire collection, however, 70% of the volume of the entire collection because large objects are often deposited here) which are classified according to individual collections and stored in individual rooms. Besides depositories there are also restoration workshops, a disinfecting room, archive, research rooms, office rooms and other operating rooms.

The air-conditioning system in the main depository is based on air-conditioning units for individual rooms located on the top floor (under the roof above the 3rd aboveground floor, the air-handling plant is situated above the technical section of the building). The source of heat for the building is a gas boiler room with two boilers (each with an output of 234 kW) in an adjacent ground-floor extension. The air-conditioning system coolers are located on the roof of the extension. Two compressors with an input of 59.1 kW each are used for cooling and are installed in the air-handling plant. The existing air-conditioning system is on the upper limit of its output and it is not possible to connect any other rooms to it.



DEPOSITORIES IN THE APPLIED ARTS MUSEUM

Address: Husova 14, Brno
GPS: 49°11′39.685″N, 16°36′17.392″E
Lot numbers: 499

The Applied Arts Museum houses especially objects from the collections of applied arts and design. There is a depository for pottery and porcelain, glass, metals, textile, art collections from the Orient, graphic design, and a depository of photographs and new media. The number of objects stored is approximately 120,000 pcs (i.e. 60% of the entire collection, however, only 30% of the volume of the entire collection because especially small objects are deposited here).

The air-conditioning system is central allowing individual setting according to the requirements for keeping individual materials.

OPEN DEPOSITORY IN PRAŽÁK PALACE

Address: Husova 18, Brno
GPS: 49°11′43.577″N, 16°36′15.177″E
Lot numbers: 591

Pražák Palace houses the major part of sculptures (with the exception of wooden sculptures deposited in the main depository in Řečkovice) in a so called open depository. There are approximately 500 objects.

The air-conditioning system consists of mobile air-conditioning units.

Objects from collections can also be stored in so called transit depositories. These rooms meet the micro-climate requirements for long-term storage of collection objects but are used prevailingly for short-term depositing of objects before their transport to exhibitions, restoration workshops, etc. Transit depositories can be found in museum buildings (the Applied Arts Museum, Pražák Palace, and Governor's Palace) and in the main depository. Only a fraction of collection objects is stored in these depositories.

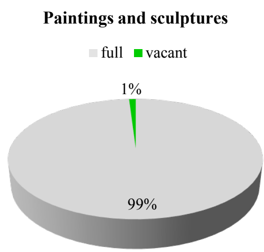
Needs Analysis

Almost 99 per cent of the collections of the Moravian Gallery in Brno are deposited in the above depositories. Owing to the space available for exhibitions, it is not possible to change the ratio between the exhibited and the deposited objects for the benefit of the first group. Moreover, some objects, e.g. photosensitive materials (paper, photographs, or textile) cannot be on display for a longer period of time. The depositories therefore keep and will keep the majority of objects administered by the Moravian Gallery in Brno.

ANALYSIS OF THE CAPACITIES OF THE EXISTING DEPOSITORIES

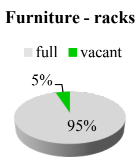
Paintings and sculptures – Řečkovice

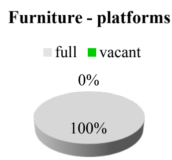
– filled to 99 %
– approx. 900 paintings are kept under provisional conditions (racks)



Furniture – 2nd floor (213)

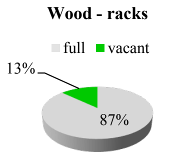
– when the exhibition from AAM is moved there, the area outside racks will be filled to more than 100 % of its capacity
– does not include long-term loans (it would be another 60 %)

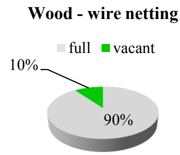




Wood – 3rd floor (316)

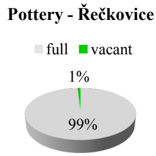
- part of the fine arts collection is stored here
- small objects only, furniture cannot be kept here

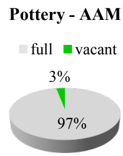




Pottery

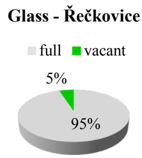
- filled to 99 % / 97 %
- only a small room in Řečkovice (53 m^2)
- AAM moving not included!

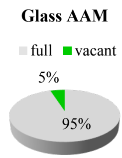




Glass

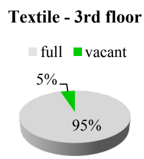
- filled to 95 %
- only a small room in Řečkovice (57 m^2)
- AAM moving not included!

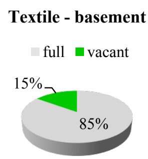




Textile

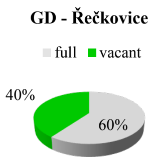
- filled to 95 % and 85 %
- only a small room in Řečkovice (57 m^2)
- AAM moving not included!

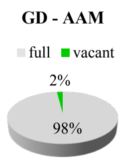




Graphic design

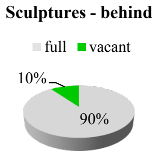
- free capacity in drawers in Řečkovice, not freely laid

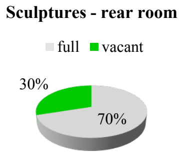




Sculptures PP

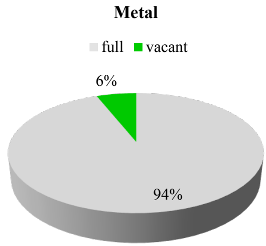
– smaller objects in racks, larger in the rear room





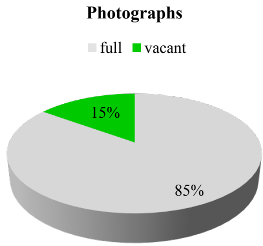
Metal objects + Orient

– 4 smaller rooms, in total filled to approx. 94 %
– AAM moving not included (296 metal objects)



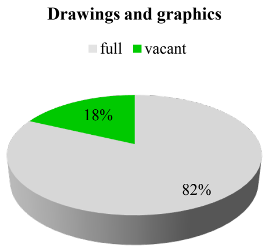
Photographs

– shelves filled to approx. 85 %
– it is difficult to keep large formats and framed photographs even now



Řečkovice – drawings and graphics

– filled to approx. 82 %
– it is difficult to keep large formats and framed objects even now



Comment: The percentage derives from the ratio between full and vacant racks/drawers/wire netting and not the number of objects deposited.

The existing depository units are filled to 91 % on average. However, individual depository units are not easily comparable due to completely different approaches to storing individual materials and their requirements for space (e.g. furniture is much different from photographs).

In 2015 the management of the Moravian Gallery in Brno made a decision to move the complete collection of modern and contemporary paintings and part of sculptures (wooden sculptures) from the basement rooms in Pražák Palace, completely failing to meet the requirements for safe storage, to the main depository in Řečkovice. Paintings partially covered with mould were restored and moved to the depository of early painting. This unification was also possible thanks to an organizational change which enabled the Collections Management Department to be established, which made the administration of collections much more efficient.

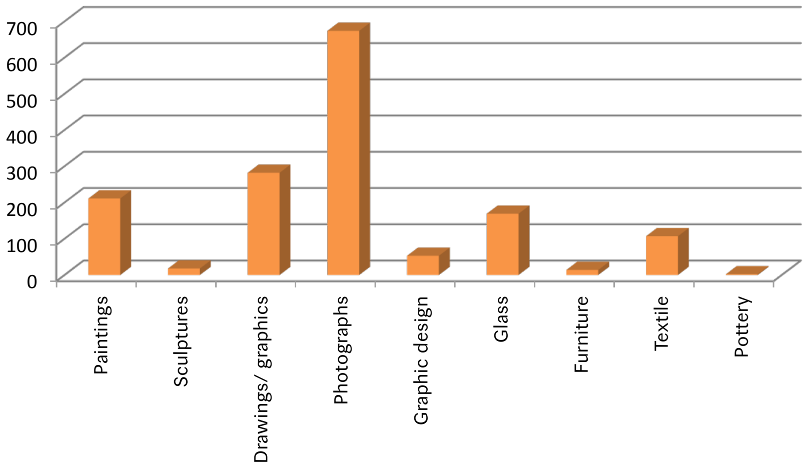
Wire netting screens in the unified depository of paintings on which paintings are laid/hanged are currently full and still approximately 900 paintings had to be provisionally laid in racks. In consequence of the above, this depository unit has been filled to capacity.

A similar situation has occurred in the depository of wood and furniture where part of the collection of modern and contemporary sculpture has been moved.

Expected expansion of the collection

In compliance with the Collection Growth Policy of the Moravian Gallery in Brno, new items should be added to the collections every year in order to expand them and increase their value.

SUMMARY OF ACQUISITIONS FROM 2014—2016:



The acquisitions in 2017 and following years focus primarily on expanding the collections continuously in connection with arranged exhibitions and the planned new permanent exhibition in the Museum of Design. It is possible to predict that besides acquisitions made on a regular basis new items will be mostly three-dimensional, often made from composite material in connection with plastics and other novel polymeric alloys.

Investment Decision

The analysis of existing depository capacities and expected expansion of the collection pose a threat of insufficient storage capacity for the collection objects administered by the Moravian Gallery in Brno.

The possibility to finance the project from the funds of the Integrated Regional Operational Programme is limited in time for organizations co-financed by the Ministry of Culture of the Czech Republic (it can be expected that it is one of the last opportunities for co-financed organizations to obtain grants from the European Union for this type of projects also for the next provisioning period). The probability that a similar project would be financed from the budget of the Moravian Gallery or an extraordinary grant of the establisher is negligible.

PROJECT GOALS

Main goal of the project:	The construction of a new depository building as a low-energy building operationally interconnected with the existing main depository, however, using up-to-date technologies and equipment.
Specific goals of the project:	1. To increase the capacities of depository areas 2. To improve the standard of deposited collections 3. To make the administration and handling of collections more efficient
Principle of the building:	The newly built depository should meet the requirements for an open depository for professionals and the general public. The spaces of the new building will be clean. All acquisitions requiring restoration or other cleaning will be directed to the existing building where there are sufficient operating and intermediate storage facilities for these purposes.

2. Investment Preparation

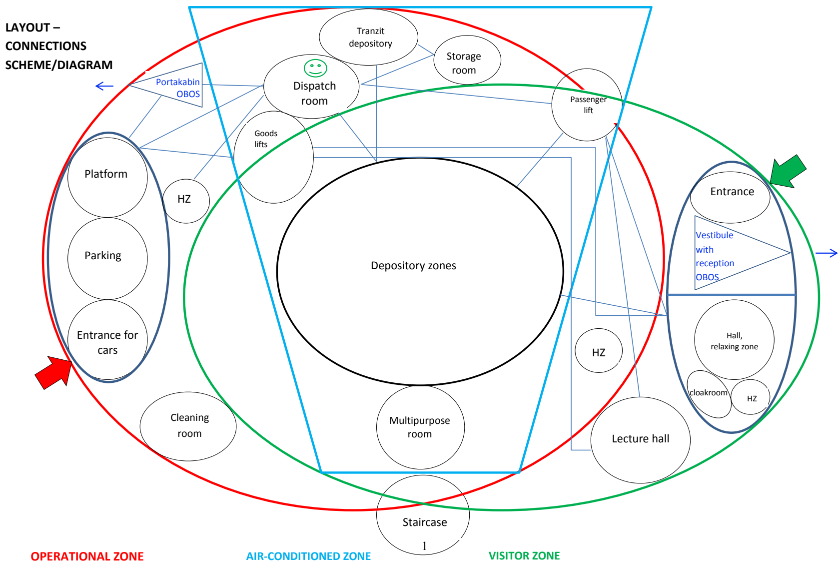
THE DESIGN PHASE

The current status of the design phase of investment preparation as of 11th August 2017

The new depository in Brno-Řečkovice will be built on plots of land of the Moravian Gallery in the closest proximity to the existing depository. Both buildings will be operationally interconnected and landscaping is included in the project. The plots of land for the anticipated construction are situated in a stabilized construction area for public amenities governed by the structure/zoning plan in force and the utilization rate for construction purposes.

The Moravian Gallery has prepared a Contract for Work concerning a public tender for the design engineer that will prepare design documentation for the building permit. The selected design engineer will subsequently ensure that the Building Authority having the subject-matter and local jurisdictions will issue the joint planning permit and building permit including their legal force and that all connected permits, decisions, consents, and opinions will be issued including disposing of comments and objections of the bodies concerned and other parties to the procedure.

Construction specifications for the design documentation for the building permit (PDSP) including an analysis of the current status in the depositories of the Moravian Gallery, justification of the need of a new depository, description of the required properties of the new depository building including layouts, technologies and equipment, and requirements for security, fire prevention, and equipment of the interior are given in an Appendix to the a.



The Moravian Gallery intends to file an application for allocation of funds from the Integrated Regional Operational Programme in mid-December 2017. Under the conditions of the Integrated Regional Operational Programme the design documentation will be submitted to the competent Building Authority together with an application for the issuance of a joint planning permit and building permit as of that date. The building permit including coming into legal force will have to be obtained before the issuance of a decision to award a grant from the Integrated Regional Operational Programme so that the conditions imposed by the given operational programme can be observed.

THE IMPLEMENTATION PHASE

The current status of the implementation phase of investment preparation as of 31st August 2017

If the grant from the Integrated Regional Operational Programme is awarded, the Moravian Gallery in Brno will invite a competitive tender for the design engineer that will prepare the design documentation for the construction including engineering supervision of the client.

Conclusion – Acknowledgement

This particular preliminary design is only one of possible designs and derives from highly specific conditions based on a combination of circumstances. Many questions still need competent answers. Anyway a large team of colleagues from the Moravian Gallery in Brno and also several external specialists have put in a great deal of genuine effort and hard work. I wish to express special thanks to Pavla Obrovská, Mirek Divin, Aleš Sládek, Jiří Bačovský, and Milan Kříž.

Let There Be Light! However, Everything in Moderation…

MARTIN DVOŘÁK

Adequate level of illumination is one of the prerequisites for good visual perception of artistic works. On the one hand there are efforts to arrange perfect lighting conditions for visitors; on the other hand it is necessary to take into consideration adverse effects of light which can cause irreversible damage to photosensitive artefacts that can even lead to their complete destruction. Let's examine individual hazards and also protective measures used in the past as well as those recommended today.

Conclusion

Light is one of the main factors influencing our lifestyle. Today we take it for granted that we simply switch the light on after dark and to light fire we strike a match or flick a lighter. However, try to imagine conditions under which our ancestors lived from time immemorial – in harmony with the night and day cycle reflecting the seasons of the year. They used to get up at dawn and went to bed at dusk. They were an inseparable part of this cycle and did not have any possibility to break it.

It was the control of fire that triggered the fundamental change. Fire was not only a source of life-giving warmth, an effective protective measure against predators, and a source of artificial light which extended the active part of the day of our ancestors and enabled them to enter places which daylight could never penetrate. Dating differs significantly, however according to the evaluation of archaeological finds (e.g. the survey conducted by the Hebrew University of Jerusalem on the upper reaches of the Jordan in the Gesher Benot Ya'aqov prehistoric site) archaeologists presented a plausible hypothesis that the predecessors of modern man (Homo erectus) were able to control fire almost 800,000 thousand years ago – it means not only to maintain and move fire from place to place[1] but to purposefully light fire. This is evidenced by archaeological surveys (e.g. the survey of the Hebrew University of Jerusalem on the Jordan where charred and blackened flint stones were discovered in 12 repetitive archaeological layers). It was a decisive turn in the development as compared to previous finds – our ancestors became emancipated and learnt

1 Retrieved from: http://zpravy.idnes.cz/praclovek-umel-rozdelavat-ohen-uz-pred-790-000-lety-tvrdi-vedci-pq8-/zahranicni.aspx?c=A081028_023526_vedatech_lf

to purposefully control fire which they had obtained from forest fires caused by lightning or spontaneous ignition only.

Besides the fact that our ancestors obtained a source of light and broke the regularity of dark nights and light days in connection to the seasons, they gained even bigger advantages – fire was a useful source of heat which enabled them to leave warm Africa and move to cold Europe. Moreover, thanks to fire hunting was more effective and so was the defence against predatory animals. Fire also started to be used for the preparation of food, which increased the nutritional value and Homo erectus had a source of useful energy.

It is interesting from the point of view of conservation of monuments that besides the above decisive changes control of fire also contributed to the creation and development of first artistic works – the oldest wall paintings which were discovered in cave systems almost all over the world (Spain, France, Bulgaria, Somalia, sub-Saharan Africa and also South America). Without artificial lighting the cave wall paintings could have never been created in the dark nooks of cave systems. The first artists must have been working in the artificial light of fire or simple "torches" and much later also stone "lamps" burning fat.

The central theme was the depiction of various animals, but also schematized human figures accompanied by abstract geometric patterns in not easily explainable roles can be found. Their purpose has not been fully clarified up to now. More theories exist – ritual libation to gods of prehistoric hunter-gatherers which should have helped them to be more successful while hunting, purely ritual and religious purposes. Some modern theories suggest that the paintings were created in a kind of ecstatic trance into which the artists were put by intentional consumption of herbs with hallucinogenic effects or by excited mental state induced by long-term stay in dark places.

It is interesting that the development was subsequently significantly inhibited, if not stopped completely. Our ancestors acquired several techniques for kindling fire which represented various manners of increasing temperature mechanically in order to achieve the ignition point of highly flammable materials (most frequently by striking or rubbing tinder, sawdust, cotton, etc.).

As a classic example we can mention the bow drill or rubbing a wooden peg or stick against a larger piece of wood.

Another technique is kindling tinder by sparks produced when striking a hard stone (most frequently flint) and steel (iron pyrite, sharpening steel).

An elegant, however, not frequent method is the concentration of sun rays passing through a lens made of a ground natural crystal.

The discovery of matches in 1823 marked a real turning point in the history of artificial lighting. They developed from the first poisonous and hazardous flammable mixtures based on white phosphorus to modern safety matches.

However, it was scientific research in the field of electricity and the invention of the light bulb which triggered really revolutionary changes. After the first experiments with arc lamps, the attention focused on the development of a light bulb. Its principle is very simple – electric current passing through a wire filament heats the filament to such a high temperature that it glows with visible light. The filaments in the first bulbs were made of carbon (carbonized bamboo), later wolfram started to be used especially because of its resistance to higher temperatures. The glass bulb is evacuated, which protects the filament from burning down. Especially bulbs with higher light output are filled with inert gas (nitrogen, argon, krypton). The eventual winner of the competition for the bulb was T. A. Edison who outperformed other inventors thanks to his business acumen. Humphry Davy, Hiram Maxim and Heinrich Göbel also lodged legitimate claims for participation in the invention, however, Edison won several legal disputes initiated by them and the bulb was eventually ascribed to him.[2]

The invention of the bulb was a revolution in the concept of natural and artificial light. Bulbs spread quickly and easily; in comparison with gas, they were much safer and relatively cheap.

In Bohemia and Moravia bulbs were used soon after their discovery and launch in industrial buildings, such as the sugar refinery in Židlochovice in southern Moravia in 1880, and also in cultural institutions. The first of them was the newly built Municipal Theatre on the Ramparts (today the Mahen Theatre) in Brno where the originally intended gas lighting was replaced by electric lighting designed by T. A. Edison himself who visited Brno personally later to see one of his earliest completed projects. The National Theatre in Prague was another electrified theatre where electric lighting was installed during the renovation following the fire of 1881; the second opening ceremony took place in 1883.

The light emitted by bulbs has a very pleasant colour spectrum similar to sun light. The production of bulbs is cheap and environmentally-friendly becau-

2 Retrieved from: https://cs.wikipedia.org/wiki/Žárovka

se no toxic materials are processed in contrast to fluorescent tubes (mercury, luminophore). On the other hand, the major disadvantage of bulbs is their low efficiency; they convert less than 5% of the energy they use into visible light. The remaining energy is converted into heat. Bulbs also typically have short lifetimes around 1,000 hours.[3]

Individual sources of light kept improving, the principle of light generation changed, new types of electric light were discovered, such as fluorescent lamps, halogen lamps, sodium lamps, the efficiency grew, lifetimes became longer, the spectral characteristics changed; however, all these improvements can, with some exaggeration, be considered mere modifications to the original ingenious invention. Light-emitting diode lamps (LED) were a more significant invention in the latter half of the 20th century thanks to their high efficiency, extremely low electric power consumption and spectral characteristics closely resembling daylight.[4]

Following the historical introduction, it would be suitable to define light and how does the eye perceive light.

Light is the visible part of electromagnetic radiation having wavelengths in the range of 390–760 nanometres (nm) between the infrared and the ultraviolet. For the basic photometric characteristics of light see below. Light has both corpuscular properties and properties of electromagnetic wave (dualism).

THE PHYSIOLOGY OF LIGHT PERCEPTION:

The human eye is a complicated optical system which, if fully functional, allows sharp and colour vision. Light enters the eye through the cornea and iris working as aperture regulating the light entering the eye and falling on the retina.[5] The lens ensures that vision is sharp. The lens shape is changed for near focus (accommodation) and is controlled by the ciliary muscle. Light rays fall on the retina formed by two types of photoreceptors where they cause chemical changes and are transmitted as electrical signals by the optic nerve to the brain:

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3 HABEL, Jiří a kol. *Světelná technika a osvětlování* (Lighting technique and illumination). Praha: FCC Public, 1995. ISBN 80-901985-0-3.

4 ČSN EN 13201-4. *Light and lighting – Measurement and display of photometric data of light sources and luminaires: LED lighting sources and luminaires.* Prague: Office for Standards, Metrology and Testing, 2005.

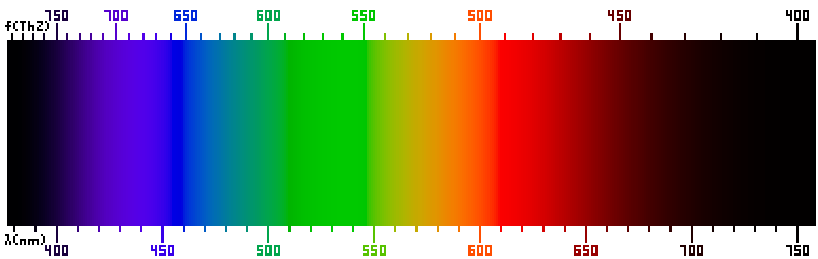
5 GANONG, William F. Přehled lékařské fyziologie *(Fisiologia Medica)*. 20th ed. Praha: Galén, c2005. ISBN 80-7262-311-7.

Rods (special very sensitive photoreceptor cells present in the retina of vertebrates) approx. 130 million cells allowing perception of contrasts in the area of very low level of light of black and white light, the so-called twilight or **scotopic vision** when the eye adapts to a very low level of light. The highest sensitivity of the eye in this type of vision is to radiation having wavelengths of 507 nm.

Cones (special photoreceptor cells in the eye retina allowing colour vision under the condition that the level of light is higher) approx. 6 million cones in the retina of three functional types with various types of photo spin – one specializes in the green colour, the other in the blue and the last in the red colour of the spectrum. This type of vision is called **photopic**, or daily vision. The highest sensitivity of the eye in this type of vision is around the wavelengths of 555 nm.

THE FALLING LIGHT CAN BE CHARACTERIZED BY THE FOLLOWING QUANTITIES:

Wavelengths of radiation [nm] – as a general rule the energy of a photon increases with the increasing frequency (i.e. decreasing wavelengths of radiation). Light having short wavelengths (blue part of the spectrum) will, therefore, have higher energy than light having longer wavelengths (blue part of the spectrum). The UV radiation photons have even higher energy.



COLOUR SPECTRUM ACCORDING TO WAVELENGTHS

Total light exposure – total level of light and time for which the light shines [lxh/year, or possibly Mlxh/year]

CANDLEPOWER [cd] is luminous flux emitted by a point-source per unit solid angle in certain direction.

LUMINOUS FLUX [lm = cd.sr] is radiant flux [W] generated by a source in relation to the spectral response of the human eye.

LUMINOUS INTENSITY [lx = lm.m^{-2}] is luminous flux falling on 1m2. By way of illustration, luminous intensity on a bright day is approximately 104 lx, luminous intensity of interior lights is in dozens to hundreds lx, and of full moon 0.3 lx.

LUMINANCE [cd.m^{-2}] is a photometric measure of the luminous intensity per unit area of light travelling in a given direction, the amount of light from a particular area that falls within a given solid angle. E.g. the luminance of a road illuminated by public lighting is approx. 0.5–2 cd.m^{-2}.[6]

POSSIBLE ADVERSE EFFECTS OF LIGHT

Besides positives (life on Earth, one of key prerequisites for photosynthesis and growth of plants, vision, etc.) light has some negatives too (some wavelengths are hazardous to humans and other living organisms, some are fatal).

From the perspective of heritage conservation, it is important that certain wavelengths have degradational effects on some groups of objects (from the visible spectrum especially near-UV radiation). The extent of damage to objects in collections depends especially on the following factors:[7]

Characteristics of falling light identified by:

RADIATION WAVELENGTHS [nm] the energy of a photon increases with the increasing frequency (i.e. decreasing wavelengths of radiation). Light having short wavelengths (blue part of the spectrum) will, therefore, have higher energy than light having longer wavelengths (blue part of the spectrum). The UV radiation photons have even higher energy.

6 Medřický H. Artemide – a memo.

7 ČSN EN 13201-4. *Light and lighting – Measurement and display of photometric data of light sources and luminaires: LED lighting sources and luminaires.* Prague: Office for Standards, Metrology and Testing, 2005.

LUMINOUS INTENSITY E MEASURED IN LUXES [lx] – surface density of luminous flux per unit solid angle.

TOTAL LIGHT EXPOSURE – total level of light and time for which the light shines [lxh/year, or possibly Mlxh/year]

Characteristics of the object illuminated identified by:

THE TYPE OF MATERIAL AND ITS CHEMICAL COMPOSITION (e.g. paper, textile, leather, oil painting, etc.);

THE CURRENT STATE OF THE ARTEFACT ILLUMINATED (e.g. age, general state, extent and type of damage, history of previous exposure to light).

The falling light initiates photochemical reactions in individual types of material, which subsequently causes their destruction.[8] The higher energy of the falling luminous flux, the greater damage is caused. As mentioned above, various materials are not equally photosensitive. The threshold sensitivity of a group of extremely photosensitive materials (e.g. paper, textile, some pigments and dyes) is very low; therefore, even photons with low energy levels can induce irreversible chemical changes in them. These destructive changes affect various materials in different ways. Most frequently the mechanical strength decreases, cracks appear, and the material becomes fragile. This process is often accompanied by changes in the colour (the colour of the material fades, the material becomes yellowish, etc.). It should be emphasised that the photochemical reaction sometimes initiates processes of degradation which are also influenced by other factors, such as the ambient air parameters (current temperature, humidity, the level and type of air pollution, the presence of oxygen, etc.).

It is important to be aware of the fact that the adverse effects of light are cumulative in time. It is, therefore, desirable to reduce light containing some ultraviolet radiation (daylight, fluorescent lamps, high-pressure discharge lamps, halogen lamps) to the minimum or completely prevent it from falling on extremely photosensitive objects, or possibly provide effective filter blocking UV radiation.

8 S. Gerlach, H. Römich, M. Picollo, C. Cucci, B. Lavédrine, G. Martin, M. Dvorak. Proc. of the conference "Methods and benefits of environmental testing and engineering", organised by Confederation of the Europ. Environmental Eng. Soc. (CEEES), Conference, 14th and 15th May 2003, Nurnberg, Germany, 2003.

Individual materials of or from which the protected artefacts are made can be classified into four basic categories according to their photosensitivity. Maximum luminous intensity is recommended for each or these categories. This classification is intended for reference purposes only and it is necessary to deal with each object individually. For example, glass having manganese compounds in its structure can be affected by so called glass solarisation, i.e. its colour shade becomes pinkish. It is, therefore, necessary to reduce the luminous intensity. Objects in museum collections which are not made from single material must also be assessed individually, e.g. if varnish or glaze contains organic photosensitive pigments, the entire painting or other object must be considered more photosensitive.

MAXIMUM LEVELS OF LUMINOUS INTENSITY RECOMMENDED FOR INDIVIDUAL MATERIALS ACCORDING TO THEIR PHOTOSENSITIVITY (UNDER ČSN P CEN/TS 16163)

Photosensitivity category – upper luminous intensity limit [lx]	Prevailing material – type of object
High photosensitivity – Recommended max. luminous intensity **50 lx**	TEXTILE – dresses, costumes, tapestries, ethnographic objects, natural fibres (silk), covers, upholstery, some carpets PAPER – fine arts and documents written on paper of poor quality, faded artworks, aquarelles, some unstable colours or organic pigments, inks, low quality newspapers, seals, some prints, manuscripts, hand-coloured prints and colour photographs, photographs made using the oldest cameras and photographic techniques, slides, wallpapers
Moderate photosensitivity – Recommended max. luminous intensity **50 lx**	TEXTILE – dyed with high quality pigments, indigo, dyed wool textiles, rag paper WOOD – painted and coloured wood PRODUCTS OF NATURE – feathers, furs, coloured leather, botanic objects
Low photosensitivity – Recommended max. luminous intensity **200 lx**	PAINTINGS – oil paintings, temperas painted by quality pigments, some frescoes, varnishes, gouaches SOME PRODUCTS OF NATURE – bones, ivory, horns, shells, undyed wood MODERN COLOUR PHOTOGRAPH SOME PLASTICS
Resistant – Recommended max. luminous intensity – according to situation, unlimited	Stone, glass, majority of metals, minerals, enamel, unglazed and unpainted pottery, porcelain, mineral pigments

Historical shading systems[9]

As mentioned above, degradation caused by light has cumulative effects in time. It is, therefore, necessary to bear in mind possible hazards caused to works of art by light when planning temporary and permanent exhibitions, or simply storing the works. It is enough to follow a simple rule that light cannot cause damage, if it is prevented from falling on the given artefact, or if the period for which light can affect the work is minimized.

Our ancestors were aware of it. We can usually find several systems limiting or blocking out daylight in the interiors installed in chateau wings directly exposed to light. Besides window shutters, these systems often included adjustable or manoeuvrable Venetian blinds or fixed blinds on the outside of windows. Thanks to them the amount and intensity of sunlight entering the rooms could have been easily controlled. In the interior other shading systems were used – textile or paper roller blinds, net curtains, curtains, and internal single-piece wooden shutters. These measures naturally had more purposes; besides limiting exposure of valuable interior equipment to light, they increased safety, enabled basic temperature control, etc.

We can use Hluboká castle as a good example to illustrate this point.[10] The current appearance of the new castle built in the romantic Tudor gothic revival style inspired by Winsor Castle was designed by the architect Franz Beer to order of Adolf II of Schwarzenberg who had the former baroque building demolished. The construction work took more than 30 years.

From the perspective of heritage conservation, it is important to note that already the original design incorporated shading systems of representative rooms with large windows and glass walls situated in the southern wing of the castle (e.g. Morning Salon). The architect suggested a very modern technical solution to the problem of the light control surprisingly reflecting our current trends. He intentionally implemented a multi-level shading system allowing certain manoeuvrability and light control. His concept was very sophisticated as he was aware of the basic principles of dealing with the light and therefore tried to control the light level as effectively as possible.

9 ZAHRADNÍK, Pavel. *Hluboká*, zámek*: Dějiny objektu* (Hluboká chateau – the history). Prague: National Heritage Institute, main office. 2003. p. 329.

10 Idem.

On the outside large windows there are shades making it possible to completely block the light out and also manoeuvrable wooden Venetian blinds controlling the amount of light entering the interiors in accordance with the intensity of sunlight during the day and in various seasons of the year. In the interior these measures included paper roller blinds and also textile curtains on all windows.[11] This combined system has been designed to enable the users to optimise the amount of light at any time of the day or night or season according to their requirements and for their domestic comfort but also for the purpose of protecting photosensitive artefacts in the interior.

Contemporary preventative measures

Nowadays innovative and flexible approaches to the protection of historical artefacts from adverse effects of the light can be pursued.[12] New sources of light on the market are highly effective, have low power consumption, and very good properties of light. It is necessary to adopt a comprehensive approach when ensuring optimum lighting conditions with proper luminous intensity that will not pose a risk of damage to photosensitive works of art.[13]

The major problem lies in two contradictory demands which should be satisfied when installing any exhibition. On the one hand, the visitor wants to enjoy a great viewing experience thanks to clear visual perception of the exhibited object allowing them to see the real colours and all details, for which a high light level is required. On the other hand, it is for the benefit of the artefact protection to require the lowest possible level of luminous intensity minimizing adverse effects of light. The technical solution for lighting in galleries, museums and historical monuments is usually a matter of compromise between these two points of view where the protection of exhibits should prevail.

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11 Troupová, Ivana. Personal interview.

12 OPSTELTEN, J. J. The establishment of a representative set of test colours for the specification of the colour rendering properties of light sources. CIE 20th session, 1983, D112/1–4.

13 LI, Cheng, LUO, M. Ronnier, LI, Changjun and CUI, Guihua. *The CRI-CAM02UCS colour rendering index.* Color Research, 2012, vol. 37, isme 3, pp. 160–167. [cit. 31. 10. 2014]. Available at: http://goo.gl/56iA40.

One of effective methods is replacing originals of photosensitive objects (photographs, drawings, graphics, etc.) with reproductions. Thanks to modern equipment it is possible to make faithful copies and the sensitive originals can remain is safe depositories and be exhibited on special occasions only. The conditions in depositories are more favourable – photosensitive artefacts can be stored there in the dark and some additional measures can be implemented (e.g. microclimate control of museum cases, controlled atmosphere without pollutants, etc.).

Manners of Protection

Logically, the most effective measure against adverse effects of daylight is blocking or filtering it out. Based on positive historical experience exterior elements can be used (e.g. shutters, blinds, awnings) usually combined with protective elements in the interior (e.g. curtains, roller blinds, internal shutters, window glazing, walls painted with titanium or zinc white partially absorbing the UV portion of visible light). Some additional modern measures can be employed (e.g. UV plastic film, or UV varnish on the inside of window glazing).

When taking these protective measures, it is important to select reputable manufacturers and branded products really having the stated properties. It must be borne in mind that the efficiency of these measures decreases in time and some luminous characteristics should be checked by standardized measurements at regular intervals. The selection of appropriate light sources[14] is another important step. Besides suitable luminous intensity, operating mode and connected total luminous dose, it is advisable to take into consideration the wavelength characteristics of the used illumination and the UV portion. It is recommended to filter out radiation emitted by some sources of artificial light. The potential adverse effect of artificial light can also be reduced by positioning properly the source of light and the artefact illuminated.

As mentioned above, it is advisable to monitor the overall lighting situation, the luminous intensity, portion of falling visible light and UV radiation, and total exposure to light. Illuminometers can be used to check the instant level

14 CSN 12464-1. *Light and Lighting – Workroom lighting: Part 1: Indoor working spaces.* March 2012. Prague: Office for Standards, Metrology and Testing, 2012.

of luminous intensity; however, long-term monitoring by means of electronic measuring systems (data loggers) is more suitable.

Data loggers record data over time and store the data in memory. Their position is essential for the recorded data to accurately reflect actual lighting situation. The staff should be advised not to move or cover the data loggers to prevent data distortion.

Actinometers are used to measure cumulative doses of falling light.[15] An actinometer is a disposable mat to which a layer of special photosensitive substance is applied. This substance changes colour by the action of the falling light and we can read an approximate light exposure in a calibrated colour scheme.

Another possibility is to use special electronic data loggers which continuously record the amount of falling light and store the recorded data in memory. The major disadvantage of these apparatuses is their comparatively high purchase price. They also need regular maintenance, it is recommended to have them calibrated in a specialized service and maintenance shop once a year.

The so called **illumination card of a monument**, a record describing the development of the exposure of a given building to light, is very useful in relation to photosensitive artefacts. The data collected enable managers to formulate an effective strategy for the protection of objects against light when exhibitions are planned, artefacts are on loan, the position of exhibits in exhibitions should be decided, etc. so that the threatening adverse effects of light can be minimized.

Conclusion

Light is one of the essential prerequisites for life on Earth. Recent technical and technological advances have opened up exciting possibilities for illumination. Many various lighting systems and light sources are on the market and each of them is specific and suitable for a different purpose. When dealing with the problem of illumination in the interiors of historical buildings where highly photosensitive artefacts are kept and exhibited, it is desirable to keep in mind their extra protection when selecting a lighting system. The approach should be comprehensive and no potential adverse effects and properties of daylight

15 Retrieved from: http://cordis.europa.eu/project/rcn/57249_en.html – project LiDo.

or artificial light should be neglected or omitted. That is why it is necessary to monitor at least the luminous intensity, the portion of visible light and UV radiation, and total exposure to light. We must bear in mind that we are in this world for a very limited period of time only and it is our duty to take every effort to minimize excessive exposure of precious photosensitive artefacts to light so that also next generations can scientifically investigate them or exhibit them to the general public without taking the risk of irreversible damage to or destruction of these artefacts due to the higher level of absorbed light.

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Authors: Jan Červenák, Martin Dvořák, Igor Fogaš, Jana Fricová, Jan Holásek, Petr Jakubec, Michal Mazík, Martin Mrázek, Václav Němec, Alena Selucká, Zdeněk Vácha
Opponents: Jan Josef, Miroslav Černý
Translation: Lenka Zimková
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