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The Temperierung heating systems as a retrofitting tool for the preventive conservation of historic museums buildings and exhibits

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ABSTRACT

Temperierung refers basically to wall heating through pipes mounted in or on the inside of the walls. In the context of heritage preservation the Temperierung system was mainly developed by the State Office for Non-State Museums in Bavaria for heating and climatization of museums and exhibit buildings. Based on the ongoing research project "Temperierung as a Tool for Preventive Conservation—An Assessment" a close and interdisciplinary collaboration is established between building physicists, conservators and practitioners from 18 selected museums. The paper highlights the different existing Temperierung systems within the project, main components of the system and different types of application. The main principles of the technique are explained and compared to more commonly known heating systems like convector/radiator heating and wall/floor heating. Preliminary results of the measured indoor climate and effects of the Temperierung heating system of several chosen museums are presented. The impacts of the indoor climate to the conservation of artifacts, influenced by Temperierung heating, are discussed with typical methods of indoor climate assessment and with conservational assessment. The detailed and neutral description of Temperierung heating gives a basis for planners and persons in charge for retrofitting historical museum buildings.

1. Introduction

Temperierung refers basically to "wall heating through pipes mounted in or on the inside of the walls" [1]. In the field of heritage preservation, the Temperierung system was mainly developed by the State Office for Non-State Museums in Bavaria. The main protagonist and developer of the Temperierung heating system and its principles was Henning Großeschmidt, a member of this state office. Temperierung has been recommended as a heating and climatization system for enhanced climate stability in museum buildings. However, the impacts of this empirically developed system on the buildings, their indoor climate and the housed collections have not been subject of a systematic scientific investigation yet. The Temperierung heating system or method of Temperierung is described in e.g. Großeschmidt [2–4] und most recently in Großeschmidt [5]. The description of early types of Temperierung systems like wall frame Temperierung can be found in Assmann and Großeschmidt [6], and also in Großeschmidt [2]. In this literature there are only positive effects postulated which are critically discussed by other authors, e.g. Arendt and Hausladen [7] or Gronau [8]. One of the main critic concerns is the often postulated attribute of Temperierung as an energy-saving measure. The most recent major piece of literature about Temperierung, bilingual published in German and English, is a collection of articles by Kotterer et al. [9]. There are no critical articles in this collection about disputed effects of Temperierung. In Krus and Kilian [10] and also Künzel [11,12] it is concluded, that Temperierung is rather not energy-saving, but this should be lower in ranking compared to the positive effects for preservation. Many authors describe a positive effect mostly in sense of conservation heating in general to the building, but not in terms of preventive conservation to artifacts due to the indoor climate influenced by Temperierung. Only a few investigated the effects of Temperierung to the indoor climate and evaluated the indoor climate for the questions of preventive conservation in detail, e.g. Kilian [13]. The cold wall effect, first discovered and described in Ranacher [14] and Ranacher [15] can have serious negative impact on paintings hanging on outside walls. Temperierung is recommended to prevent this cold wall effect.

Under this prerequisites the research project "Temperierung as a Tool for Preventive Conservation—An Assessment" has been

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Table 1
The Temperierung systems can be grouped in three main groups (main application) and nine subgroups.

Main groups	Sub groups
Heat pipe in-wall	In-wall in brick wall
	In-wall in studwork (dry walling)
	In-floor
Heat pipe on-wall	Tight contact to the wall, pipe in mortar bed
	Minor contact to the wall, pipe mechanically mounted
	With distance to the wall surface mounted
	With distance to the wall surface, behind a panel
Heat pipe in wall frame	Closed wall-/floor frame
	Open wall-/floor frame

implemented in the year 2011. The project is based on a close and interdisciplinary collaboration between building physicists, conservators and practitioners from 18 selected museums in Bavaria, under the lead of State Office for Non-State Museums in Bavaria. All participating museums have been newly equipped or retrofitted with a Temperierung heating system between 1987 and 2011. The impacts of these Temperierung heating systems on the indoor climate and on the collections will be assessed within the project. On one hand, the influence of the Temperierung systems on building components and indoor climate are investigated and assessed from the building physics point of view. On the other hand, the assessment of the impact from the indoor climate generated by the different Temperierung systems on the preservation of the collections is the subject of the conservator's examination. Criteria for choosing single artifacts are – besides their material – the extent and quality of existing documentations and the duration of the exposition toward a climate created by a Temperierung system. Changes of the state of preservation within a detectable time span should be reproducible documented and evaluated.

2. Temperierung systems of the participating museums

2.1. Temperierung systems

The arrangement of the heating pipes of a Temperierung system is in its basic layout located at the base of the outer wall. The different systems are grouped into three main groups and three sub groups. Altogether nine systems are described in Table 1.

The three main systems are schematically shown in Fig. 1: in-wall heat pipe, heat pipe in front of the wall and heat pipe behind an additional frame similar to hybrid air-heated panel heating. The different effects of heat transmission are illustrated schematically. The heat transfer occurs by direct heat conduction through the building component e.g. wall, heat transfer by convection and radiant heat transmission. The Temperierung system behind a wall frame has a special cavity construction for warm air heating. It is an older system and not built anymore due to high costs of an additional frame and to the conservational problem of hidden original surfaces.

In Table 1 the different Temperierung systems are grouped. Further systems exist which are basically similar and refer to the introduced systems. One variation, which is not explicitly shown here, is a heat strip mounted at the base of the walls, because this type is not used in any of the surveyed museums. One further not distinguished criterion is the heat medium. Usually hydronic warm water heat pipes are used, but also electric heating cables are common. Sometimes electric powered hydronic warm water systems are in use. The example in Fig. 2 "in-wall" and "on-wall" with and without direct wall contact are the most common systems, which are generally applied today. In Großeschmidt [2] the in-wall solution is already constituted as the "endpoint of development" and "ideal solution for solid constructions". Wall frame Temperierung systems similar to hybrid air-heated panel heating are divided in open and closed systems depending whether the room air has direct contact to the heat pipe or not. For the different Temperierung systems different ways of heat transfer occur. It is depending on whether the heat releasing device e.g. heat pipe, is in direct contact to the wall or not. Without wall contact, the heat transfer occurs via convective heat transmission and radiant transfer. The efficiency of heat release of the heat pipe depends on the combination and share of the different heat transfer mechanisms. In case of wall contact there is an additional heat transmission via heat conduction. The type of contact is essential to the possible share of the heat transfer by conduction. For Temperierung systems with strong contact as like heat pipes in-wall, the heat transfer occurs directly by conduction. Only as secondary effect there is a convective heat transmission at the surface of the wall that is heated. This effect occurs also with heat pipes on-wall if they are covered with mortar, and also with heat pipes on-wall if they are in contact with the wall with mechanical mounting but then in a lower order. Secondary effects may occur on heated up wall regions adjacent to the heat pipe or heating surface.

2.2. Differences of Temperierung to other heating systems, technique of Temperierung and conservation heating

The differences to conventional heating systems like panel heating or radiator heating can be indistinct if a Temperierung system is planned and built similar to these systems. If the system is planned in wall with several heat pipes arranged one upon other or side by side it may be similar to conventional wall heating or panel heating. Main characteristic to Temperierung systems is not a full area application but a lengthwise application as a heating stripe, even if there is an area effect to the wall, as described by Großeschmidt [2]. By use of a mini radiator heater or a heat pipe radiator or several heat pipes above each other or side by side on-wall without wall contact mounted, a Temperierung system can be similar to a conventional radiator heating. The water supply of a radiator heating system is operated at the same or even higher temperature level than it is required for Temperierung. A distinct attribute of radiator or convective heating compared to Temperierung is a concentrated heat release with optimized convective heat transfer. For a Temperierung system with correctly chosen dimensioning it is characteristic to limit the convective heat release, to avoid disadvantageous effects on conservation and energy consumption which may arise with to intensive convective heat release. In earlier Temperierung systems like skirting heating with mini convectors this negative effect was not understood thoroughly enough and therefore not considered yet.

Also there are differences to conservation heating. As mentioned before conservational heating is used for stabilizing indoor humidity to a save range to prevent mold growth [16]. Conservation heating uses the property of water vapor of varying its partial pressure in air with the level of temperature. Meaning, conservation heating will reduce relative humidity by heating up the indoor air. With less heating, relative humidity will rise up to the value of the natural level of the unheated building. This results in a seasonal sliding temperature behavior of the indoor climate with a more or less stable relative humidity. This can be a goal for a Temperierung heating as well. The conservational heating is typically understood for heating only indoor air. This may be done by any heating system, adequate for the particular building. Heating up building components is not intended. Conservational heating with radiators or convectors may also have disadvantages in a poor microclimate around the heating device because of concentrated heat release and in permanent hot and dry microclimates and dust movements.