Improving the (museum) indoor climate in a flooded castle

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ABSTRACT: Amerongen Castle, built in de period of 1674-1680, is an acknowledged special national museum with a historic cultural value (Kanjerproject). Next to the monumental value of the building, it has a special collection that exists of for example a 'Van Meekeren' cupboard, a valuable atlas called 'Amsterdam 1724' and painted portraits of monarchs like Willem de Zwijger. The building and the collection are subject to deterioration. As a result of a flood of the river Nederrijn, the basement was completely flooded with water in 1993 and in 1996. This made the deterioration worse. For a period of approximately a year and a half ICN (The Netherlands Institute for Cultural Heritage) has been measuring the indoor climate in the castle. It appeared that the indoor climate was indeed not favourable for the conservation of the collection. The purpose of the work is to understand the effects of flooding of a monumental building, to understand the impact of visitors and the presence of hygroscopic materials on the indoor climate. Finally the indoor climate of the building should be improved.

On the basis of the measurements made by ICN the indoor climate of the different museum rooms was mapped. For the judgement of the indoor climate several techniques have been used, namely the climate evaluation chart, the climate evaluations map and the climate evaluation tables. A simulation model has been used to study the effects of flooding, visitor impact and hygroscopic materials in several museum rooms of Amerongen Castle. Finally the model was used to predict the effects of additional heating.

The indoor climate of the building has long been influenced by flooding in the past. Visitors of the museum rooms nowadays influence the indoor climate with their heat and moisture production. Generally, the heat production of persons is normative for the relative humidity in the room compared to the moisture production. The result is a decrease of the relative humidity in the room and an increase of RH near the cold walls. It appears that the indoor climate also depends for a large part on the furniture of the room. It is stabilized by the presence of hygroscopic materials in the room (furniture, carpet, curtains, etc.). The library e.g. has a filled bookcase. The presence of these hygroscopic objects (books) in the library seems to be responsible for the comparatively stable relative humidity, in combination with the use of a mobile dehumidifier.

Two studied heating systems (humidistatically controlled heating and floor heating) will lead to a more favorable indoor climate. Floor heating will be applied in the basement and the hall and long corridor on the first floor (beletage) and the humidistatically controlled heating system in the remaining museum rooms. The results seem to be promising.

1 INTRODUCTION

Castle Amerongen was built in the period from 1674 to 1680. It is an important governmental museum with a large cultural historical value. Besides the important value of the monumental building itself it holds an important museum collection of objects like 'the Van Meekeren' cabinet, an important and valuable atlas of Amsterdam 1724 and the kings paintings like Willem de Zwijger. The Dutch castle is located in the middle of The Netherlands at the river foreland of the river Nederrijn. Part of the building is still in use for a living function.

The building as well as the collection are in a process of slowly being deteriorated. In 1993 and 1996 the building was flooded by the river Nederrijn. The basement of the building at that time was full of water.

The indoor climate of the building was measured in a measurement campaign from 2003 to 2004. The measurement results were compared to guidelines for the preservation of the museum collection and

the building itself. The comfort of the people was decided to be less important. The measurement campaign is described in section 2. The guidelines for preservation of collection and building are determined in section 3. The discussion on the indoor climate and the effects of visitors are described in section 4. The improvement of the indoor climate and the measures to be taken are discussed in section 5. The paper ends with the conclusions in section 6.

Figure 1. Amerongen Castle (a) and some museum rooms: the Grand Saloon (b), the Library (c), the basement (d) and the Tapestry Room (e).

2 MEASUREMENTS

The Netherlands Institute for Cultural Heritage (Instituut Collectie Nederland, ICN) is a leading knowledge institute for the preservation and management of moveable cultural heritage. The institute started a measurement campaign for one and a half year in the castle in 2003. Long term measured parameters were air temperatures, air relative humidities, inside surface temperatures of external walls and light and UV intensity levels. Besides the outdoor climate was measured. Apart from these long term measurements short time measurements like ventilation/infiltration measurements and infrared thermography were conducted.

3 GUIDELINES

The results of the indoor climate were compared with guidelines for the preservation of building and collection. The aim of these guidelines is to minimize the deterioration of the valuable collection and the building itself. In the Netherlands these guidelines originally were formulated by ICN. At the moment these guidelines are under construction. Internationally ASHRAE (the American Society for Heating and Refrigerating Air Conditioning Engineers) formulated classes for the indoor climate in museums. The control of relative humidity is most important for the preservation of most collections. A lower limit of about 40 %RH is important to preserve materials from drying out. As an upper limit for the indoor air relative humidity 60 %RH is held. Relative humidity at cold surfaces should be limited to a maximum of about 80 %RH to protect surfaces for mould formation. Fluctuations of relative humidity should be avoided to prevent objects from contraction and expansion.

The day lighting of objects is also an important deterioration factor. The UV component should be eliminated and the product of exposure time and intensity value should be limited. A way to do so is making use special spectral filters for windows illumination sources and limitation of intensity and exposure time.

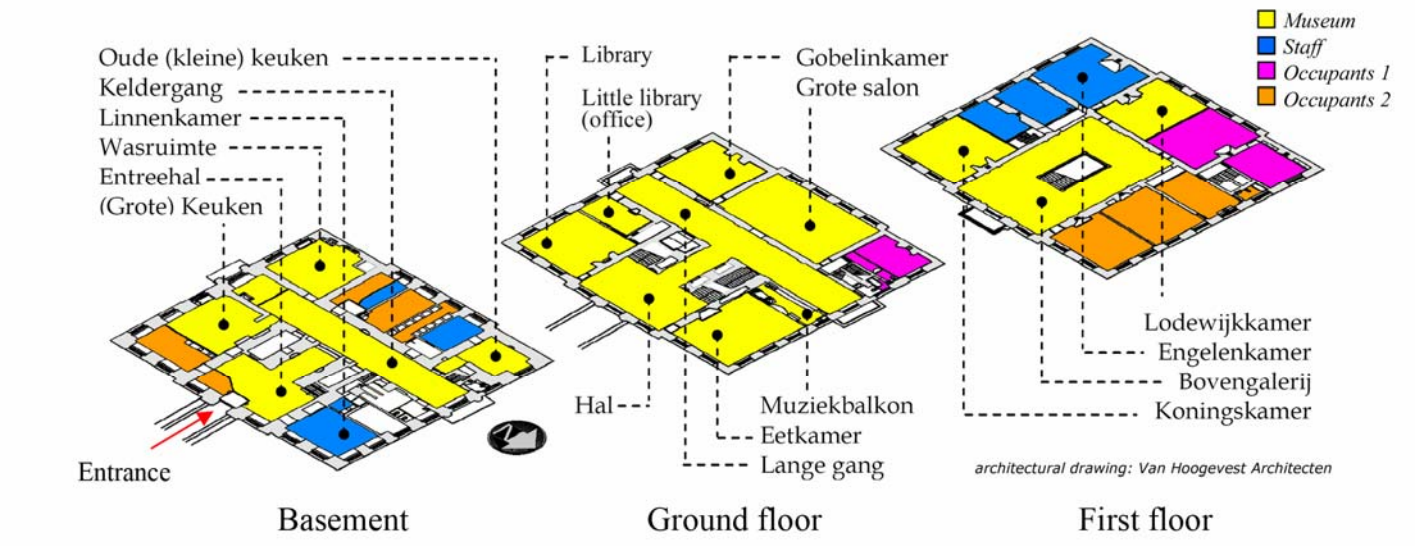


Figure 2. The museum rooms of Amerongen Castle with the different functions of the rooms.

4 EVALUATION TECHNIQUES

The indoor climate of the museum rooms in Castle Amerongen was evaluated making use of different techniques. For these purposes climate evaluation charts, climate evaluation tables and floor plan sections were constructed. The climate evaluation chart was developed at Eindhoven university of Technology (Martens, 2007). It consists of a psychrometric chart with upper and lower guidelines for temperature and relative humidity (figure 3). These limits form a (blue) evaluation area. Measurements of temperature and relative humidity falling within this area are within the guidelines for preservation of the objects. The colors of the plotted values indicate the time of season. Percentages of time the measured values are within or outside the limits are indicated in tables. The place in the table corresponds to the place in the psychrometric chart, in relation to the blue marked area (to the left, right, below or above). Fluctuations of temperature and relative humidity are indicated in histograms. The percentage of time of exceeding a certain limit of fluctuations per hour or twenty-four hours is indicated.

The climate evaluation tables are based on the climate evaluation charts and consist of two types of tables. The first type of table indicates the exceeding of the upper and lower limits of air temperature and relative humidity. The indication for each room is constructed analogue to the nine value table indication in the climate evaluation chart. A division in different seasons is indicated too (figure 4). For each season the values indicate the percentage of time the measured values are within the specific area of the nine area structure. The color of the middle area is an indication of values within the guidelines and is indicated in a color scale.

The second type of table gives an indication of the exceeding of maximum fluctuations for each hour and day (figure 5). Different rooms are indicated at the top of the figure. The guidelines for the maximum fluctuations are evaluated for each season. The numbers indicate the percentage of time the measured values are within the guidelines for maximum fluctuations and get a color according to the color code.

The advantage of these tables in relation to the climate evaluation chart is that in one view the evaluation of the museal room of the castle can be evaluated.

The third tool the climate evaluation floor section is based on the first type of climate evaluation table. For each room a division in four seasons is made to assess the air temperature and relative humidity (figure 6). The numbers indicate the percentage of time the guidelines for temperature and relative humidity are satisfied or exceeded. The judgment of both parameters is processed in two different areas in the floor plan of the room. The color of the area indicates the distance between the actual values and the guideline value. The extensive color coding is used for the assess of each room and each season. In this way the assess for each floor of the castle can be judged in a glance. A comparison for each room to another, e.g. for each orientation, is simple in this way.

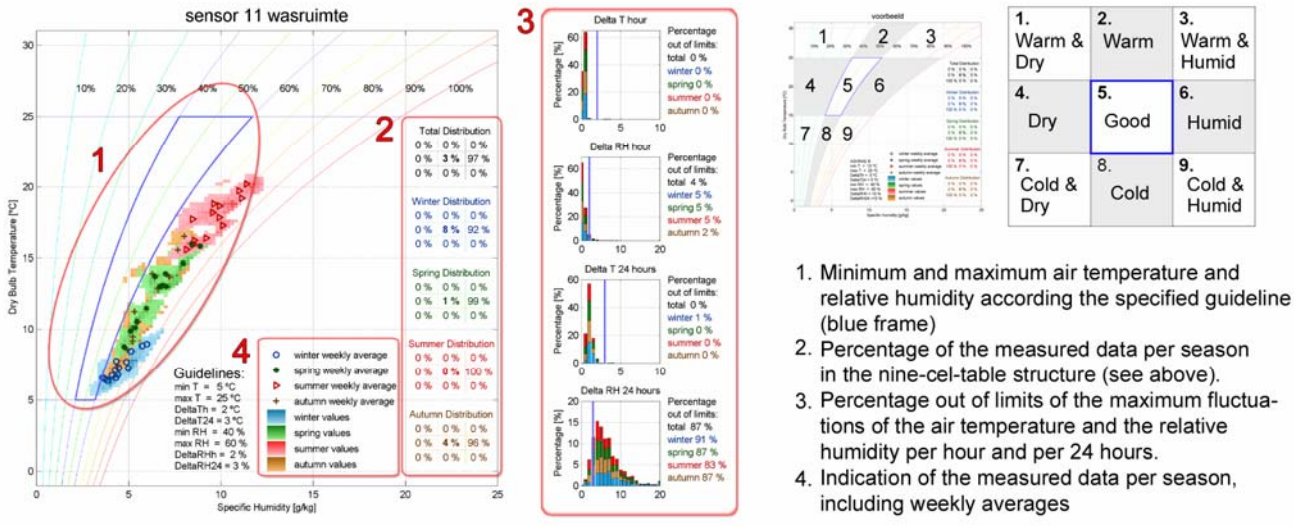
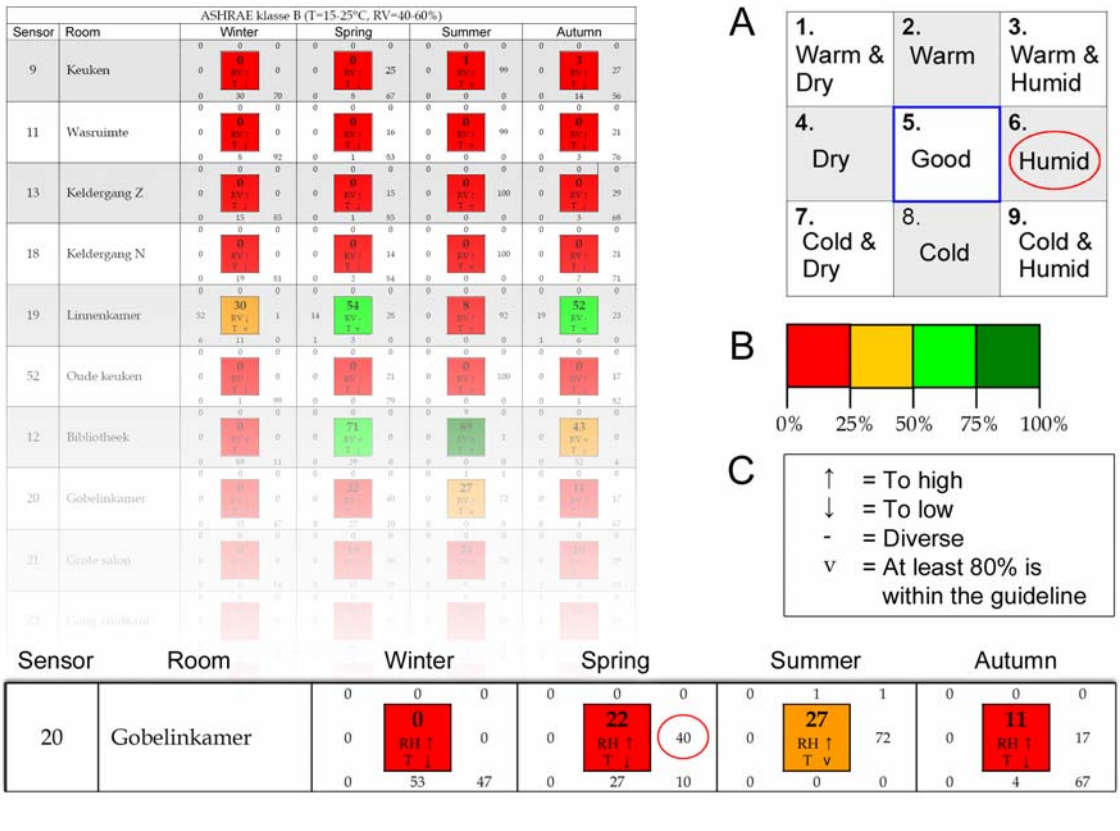
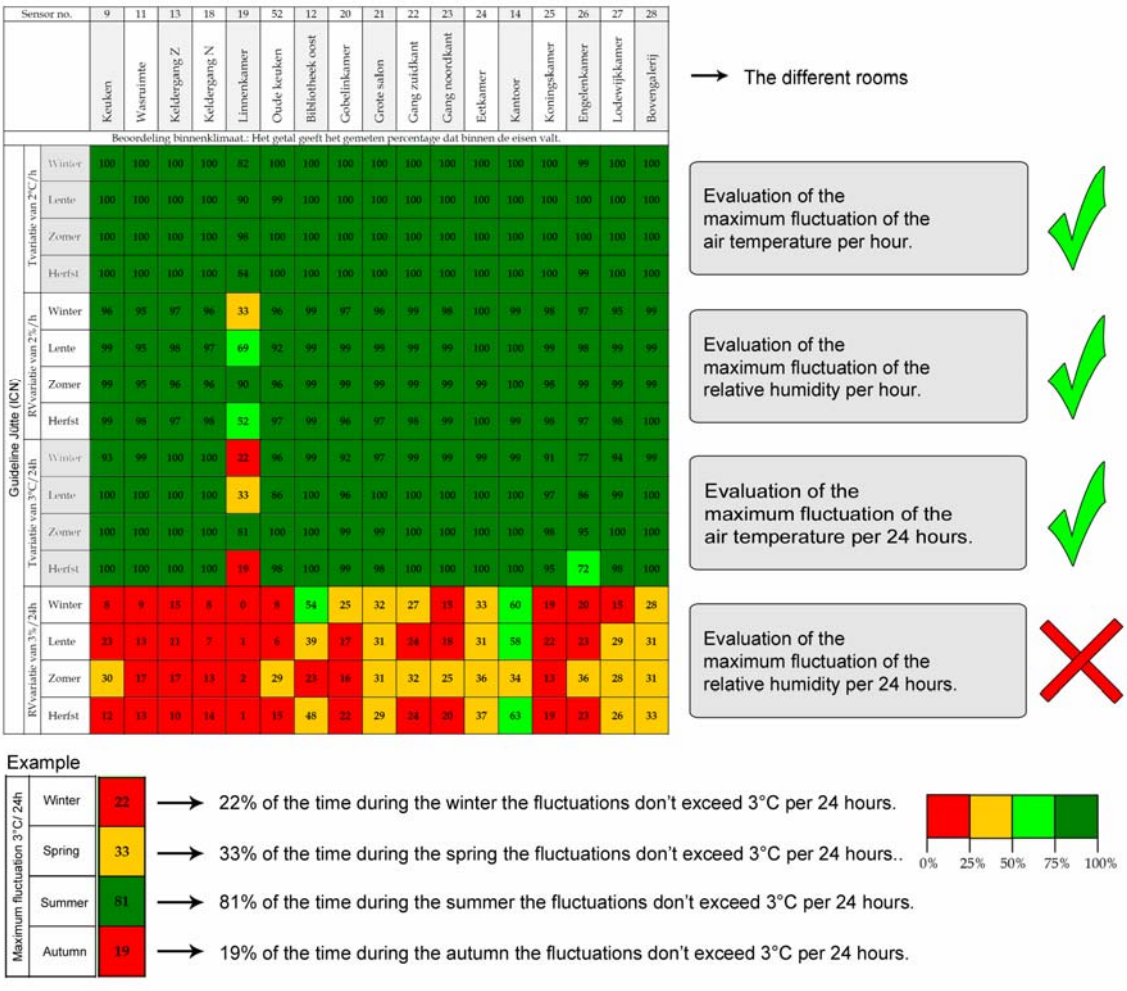


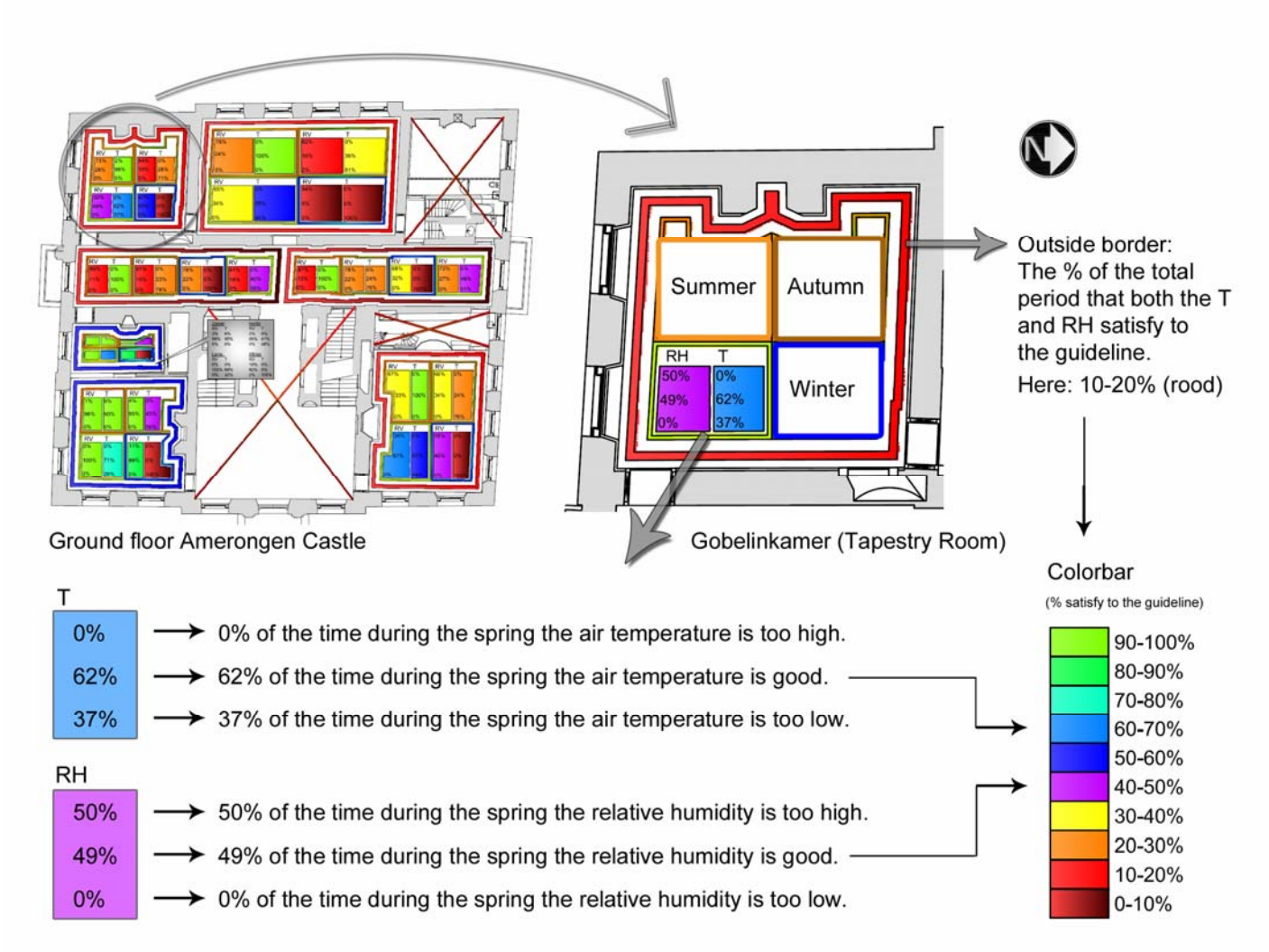
Figure 3. The climate evaluation chart of a museum room with explanation of the different components of the chart.



able (type 1) with explanation of the different components (example: Tapestry room).



season during wintertime the relative humidity in



these heated rooms is lower than 40 %RH (figure 8).

5 ASSESS OF THE INDOOR CLIMATE

Most museum rooms in the castle are not heated. The air temperature of these rooms is below 15°C most of the time. An exception is the summertime. The lowest values of air temperature are located in the basement. The relative humidity has the highest values in the basement (ϕ_{mean} > 70 %RH). The prolonged high relative humidity values in the basement indicate risks for mould generation for the basement to be the largest. In general most unheated museum rooms in the castle have high relative humidity values (ϕ_{mean} > 60 %RH) which are not beneficial for the preservation of the collection. The indoor climate of the library, the small library and the Kings room are an exception. The relative humidity in these rooms indicates values between 40 and 60 %RH (figure 7). The fluctuations of relative humidity for each twenty-four hours period are larger than 3 %. The heated rooms indicate variations in temperature too high for preservation. In the heating

5.1 *Effect of visitors*

Heat and moist production of tourists visiting the museum rooms of Castle Amerongen affect the indoor climate. In two museum rooms this effect is studied by simulation. The simulation model HAM-Base (Wit, 2006) which is developed for the study of heat and moisture in building environments was used. The heat generation by people in the room has more effect on the decrease of relative humidity than the moisture production has on the increase of RH. The result of this effect is a decrease of relative humidity in the room.

The materials of furnishing of the room have a hygroscopic nature (furniture, carpets, and curtains). In a closed empty room an increase of temperature will lead to a decrease of relative humidity. The hygroscopic materials in a room however have a stabilizing effect on RH (Padfield et al. 1996). The materials will absorb or desorb vapor from the indoor air, depending on the change in RH. This effect has been studied by simulation of the heat and moisture effects in a simulated room of the castle. An empty

room was filled by different materials and different quantities of materials (figure 9).

The library in Castle Amerongen has a large amount of hygroscopic materials. Most of these materials are formed by books in bookcases. The combination of these hygroscopic materials and a dehumidification apparatus lead to a very stabile indoor climate regarding relative humidity. The proximity of heated rooms near the library have a positive effect on the lowering of relative humidity in the library. In general there is a mutual effect of heat and moisture exchange between different rooms in the castle.

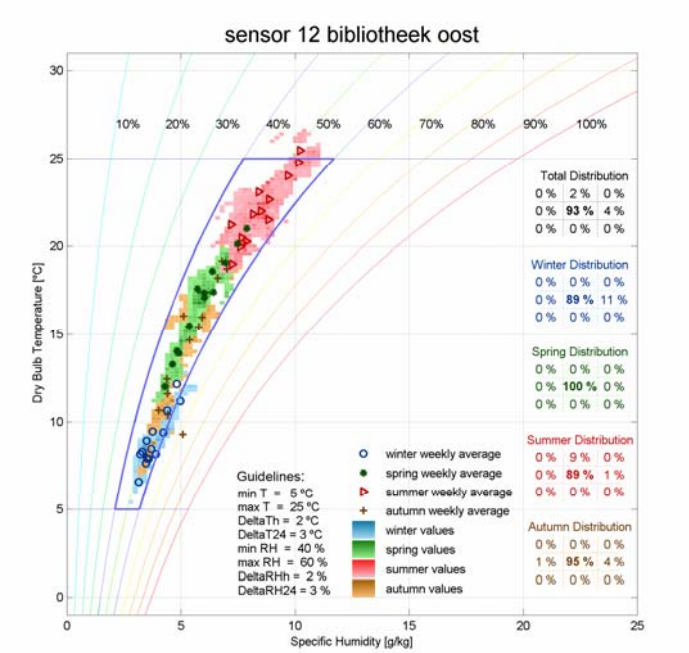


Figure 7. The relative humidity in the Library indicates values within 40-60% RH.

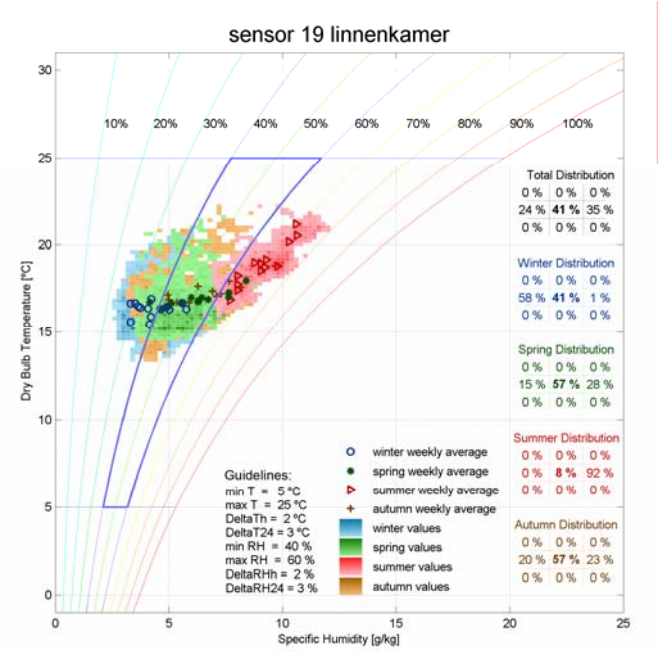


Figure 8. The relative humidity in a heated room is lower than 40% RH in the heating season during wintertime.

6 IMPROVEMENT OF THE INDOOR CLIMATE

By means of two variant studies in HAMBase possibilities to improve the indoor climate were studied.

6.1 *Conservation heating*

The first variant was a study on hygrostatic heating of the building, so called conservation heating. In this case heating is not only controlled by a thermostatic device, but also by a hygrostat. Heating will start at an upper level of RH and will stop when a lower limit is reached. In this way it is possible to control RH for the preservation of object is museum rooms. The temperature is controlled within certain limits, but is not leading for thermal comfort and has a minor importance, compared to RH. In this way it is possible that heating will continue in summertime to limit RH in the room. This kind of heating is often used in historic buildings in Great Britain which are not used for living. The system makes use of a measuring and control unit for temperature and RH. The heating source may be an electrical heating device.

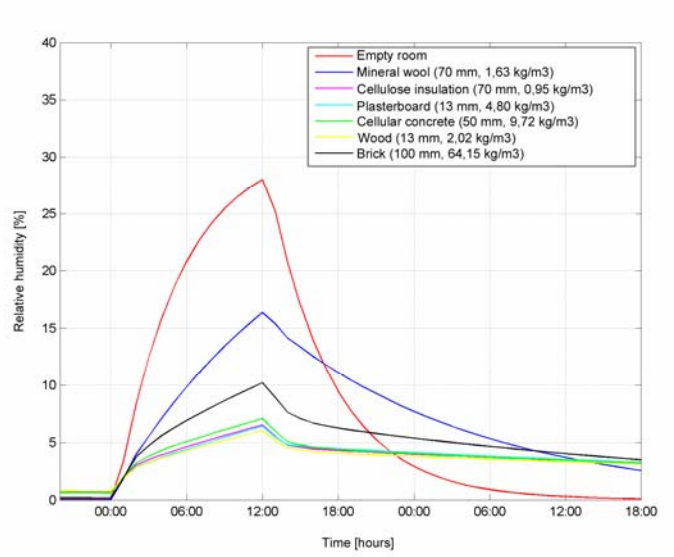


Figure 9. The relative humidity in a simulated room (V=38 m^3) with six different indoor walls (S=14.7 m^2), moistening 30g/h, ventilation 0.2 h^{-1}.

According to the simulation study it must be possible to control RH in most museum rooms on the beletage and 1st floor of the castle between 40 and 60%RH (figure 10). The setup adjustments were an upper limit of air temperature of 25 °C and a lower limit of 10 °C.

6.2 *Floor heating*

The second variant of the simulation study was a floor heating system. For the basement it was decided that a floor heating system could have a posi-

tive effect to lower relative humidity in the basement. A floor heating would have a positive effect on the drying of the walls and floor. Flooding in the past lead to an increase of the moisture content of these constructions. A drawback of the use of floor heating may be an increase of salt transport to the inner surface due to moisture transport and evaporation at the indoor surfaces.

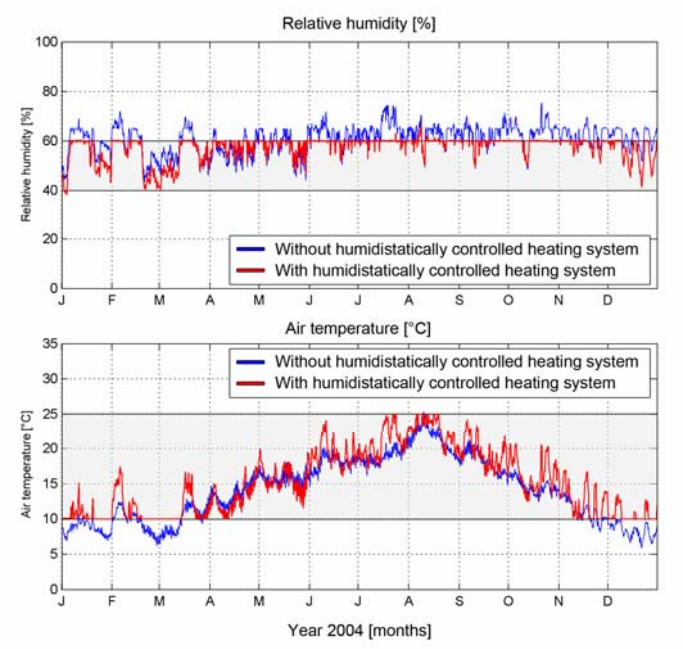


Figure 10. The relative humidity (simulated) in a museum room without conservation heating (blue) and with conservation heating (red) during a year.

7 CONCLUSION

The indoor climate of Castle Amerongen does not satisfy the museum guidelines for the preservation of valuable objects. Apart from the high relative humidity levels in most museum rooms (ϕ > 60%RH) the daily fluctuations are too high ($\Delta\varphi_{24h}$ > 3%). Especially the indoor climate in the basement has very high RH levels (ϕ > 70%RH). To improve the indoor climate in the basement floor heating is a good alternative. It has a positive effect of indoor relative humidity levels and will dry out the flooded floor and walls. Apart from this effect the heat exchange between basement and other floors will have a positive effect on the indoor climate of these other floors too. Conservation heating is a good alternative to conventional thermostatic heating. Especially for rooms where thermal comfort is not the most important factor it may lead to much more stabilized indoor climate conditions for relative humidity.

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