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HYGROTHERMAL CONDITIONS IN CULTURAL INSTITUTIONS IN LITHUANIA AND AUSTRALIA

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Abstract

The main objectives of the thesis were to get acquainted with the indoor climate requirements of cultural institutions in Lithuania and Australia as well as determine whether the chosen real buildings operate in line with them. The investigated buildings were the Cultural Heritage Centre (Lithuania), the National Museum - Palace of the Grand Dukes of Lithuania (Lithuania), and the Canberra Museum and Gallery (Australia).

Research was carried out by first becoming familiar with the temperature and relative humidity requirements pertaining to cultural institutions in both countries. Moreover, the HVAC systems in the three selected buildings that provide these conditions to the premises where collections are exhibited or stored were studied. Following that, the readings of temperature and relative humidity in three different buildings were compared to the requirements. The results were compared and suggestions were presented.

The Cultural Heritage Centre archive met the requirements of temperature during the selected months. The relative humidity values were below the minimum limit. The exhibition halls of the Palace of the Grand Dukes of Lithuania did not meet the requirements specified in the design documentation. The hydrothermal conditions in the gallery and gallery repository in the Canberra Museum and Gallery were maintained according to the requirements.

Having a building management system in the Cultural Heritage Centre archive would be beneficial. The necessary cooling and heating capacities as well as the supply of water to the humidifier should be looked into. Regarding the Palace of the Grand Dukes of Lithuania, the setpoints of hygrothermal conditions and the settings of systems that ensure them should be verified.

Keywords

Indoor climate, museum, ventilation, temperature, relative humidity

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1 INTRODUCTION

Cultural institutions, such as museums, archives, galleries and libraries, play an important role in the preservation of culture. As time passes, works of art are being created and archaeologists keep uncovering artefacts. As a result, the importance of cultural institutions is not decreasing.

All cultural institutions should ensure that the artefacts are preserved. However, the employees and visitors should not be ignored either. Depending on the purpose and type of a cultural institution, these aspects can have more or less significance and need to be taken into account when designing heating, ventilation, and air conditioning (HVAC) systems. Archives, for example, are usually not visited by many people at the same time. Therefore, the indoor climate in certain premises, where people will not spend long periods of time, might be focused on the preservation of artefacts and not the comfort of the visitors. In museums, on the other hand, it is not uncommon for the number of people to vary greatly – from a few employees to dozens of visitors during concerts or other events. Because of that, the systems should be capable of ensuring the comfort of the visitors, regardless of their number, as well as the preservation of collections. There is also the issue of the materials the artefacts are made of. Different materials need different conditions to minimise the deterioration process. In archives there tends to be less variety in the materials the collections are made of. They might also be placed in different rooms. Museums might have more problems because very different materials might be in the same premises. Ensuring suitable conditions for all exhibits, such as paintings, sculptures, clothes, books or weapons, requires more planning and consideration regarding the HVAC systems and placement of the exhibits.

The aim of this thesis was to get acquainted with the indoor climate requirements of cultural institutions in Lithuania and Australia. In order to determine whether real buildings operate in line with them, the temperature and relative humidity in three different cultural institutions in Lithuania and Australia were compared to the requirements. Improvements were suggested.

The hygrothermal conditions were analysed in the Cultural Heritage Centre archive, several exhibition halls of the National Museum – Palace of the Grand Dukes of Lithuania as well as a gallery and a gallery repository in the Canberra Museum and Gallery.

2 INDOOR CLIMATE IN CULTURAL INSTITUTIONS

2.1 Indoor climate factors

The main factors related to indoor climate that can cause the most damage to cultural collections are unsuitable temperature, relative humidity, light, air pollution, and pests /1, p. 10, 2, p. 19/. Since only the relative humidity and temperature will be analysed in the chosen buildings, these two factors will be discussed more thoroughly than the rest.

2.1.1 Temperature

An increase in temperature leads to higher chemical reaction rates. /1, p. 10./ That results in a higher rate of deterioration of materials. If the temperature is high enough or remains that way for a longer period of time, materials will deform, weaken, and some might even melt. This is especially important for the preservation of the most sensitive objects, such as video tapes, photographs, newspapers or artefacts containing rubber. Therefore, lower temperatures tend to be more suitable for most materials. However, polymeric materials, for example paint, can become brittle because of low temperature. /3./ That is why different ranges of temperatures are considered to be most suitable for different materials.

Another important aspect of temperature that should be taken into account is fluctuation. The variation of temperature can have a big impact on artefacts if it is significant and occurs during a relatively short period of time, e.g. a day. Diurnal fluctuations between the minimum during the night and maximum during the day, especially in hot dry and temperate climates, can be fairly large. /1, p. 10./ Even though it is not as severe in Lithuania, temperature fluctuations can still have very detrimental effects on collections.

The influence of temperature is also closely related to the relative humidity. This relationship is especially important when considering artefacts in enclosed spaces such as museums, exhibition halls or display cases. As temperature increases, relative humidity decreases. The decrease in temperature will lead to an increase in relative humidity. The higher the change in temperature, the higher the fluctuation in relative humidity. /1, p. 10./

2.1.2 Relative humidity

High relative humidity, just like high temperature, increases the deterioration rates of materials since there is more water that can take part in chemical reactions. Relative humidity that is too high, over 70-75%, may result in mould, fungal growth, mechanical damage, and rapid corrosion of metals. If it is lower than approximately 40%, desiccation of organic materials may occur. /1, p. 10-11, 4./

Large fluctuations of relative humidity that occur quickly are also important. Most materials are not significantly affected by such changes when they last less than an hour. A change in relative humidity means that the moisture content of organic materials changes as well. That results in the change of size of the materials. This becomes a problem if the material is constricted by other parts of the object or its own inner bulk. In such cases, it cannot expand and constrict freely. The parts that expand might be crushed while the shrinking parts might end up getting fractured. Extreme fluctuations of relative humidity will cause the moisture to move in and out of organic materials. This constant cycle of expansion and contraction will eventually cause the material to disintegrate. /1, p. 11, 4./

2.1.3 Other factors

In addition to temperature and relative humidity, there are a few other indoor climate factors that need to be considered. As mentioned previously, one of them is light. In some cases, it can cause more damage to materials than temperature. The most damaging part of the light spectrum is UV radiation. That is because the photons have the most energy when this type of radiation occurs. When photons collide with objects, they cause damage to their surfaces. Depending on the materials an artefact is made of, the yellowing of paper, fading of colours, darkening of varnishes or changes to the structure of the surface layers might occur. Sunlight is the light source that, in addition to light and IR radiation, emits the highest levels of UV radiation. However, even though artificial lighting is not as dangerous, it can also damage collections. For instance, incandescent lamps produce high levels of IR radiation. That results in an increase of temperature and might damage artefacts. Fluorescent lamps, on the other hand, tend to emit a lot of UV radiation. /1, p. 12, 2, p. 22, 5./

Another indoor climate factor that has an influence on collections of cultural institutions is the presence of pollutants. Most common outdoor pollutants that might enter the building are ozone, nitrogen dioxide, sulphur dioxide, hydrogen sulphide, and sulphuric and nitric acid vapours. Pollutants are also produced by the materials used to make museum furniture, such as display and storage cases. In addition, different types of wood, plastics, paints, adhesives, textiles, and rubber release pollutants into the surrounding air. Some acids, when the relative humidity is sufficiently high, might form salts after reacting with building materials. Acid gases react with exhibits resulting in degradation of paper and other organic materials, corrosion of metals. /1, p. 12-13./ The effects of pollutants can be very different. Corrosion of metals, discolouration, and loss of strength for textiles commonly occur because of the previously mentioned outdoor pollutants. Moreover, the rate of degradation processes caused by oxygen or water vapour, for example, might increase due to the presence of pollutants. /6./

Pests can have a considerable effect on collections as well. Insects eat most organic materials, some species can destroy wooden furniture and even damage the buildings. Other pests like rodents and birds can eat, chew, and soil collections as well as be a health hazard. Various factors – temperature, relative humidity, atmosphere, light, shelter, and sources of nutrition – have an impact on the rate of development and breeding of insects. Generally, insects can survive at about 5-45 °C. Most species eat and reproduce at about 30 °C and die when the temperature is higher than 55 °C for at least an hour. There are different methods of storing or cleaning objects that are suspected of being infested by pests. They differ depending on the materials an object is made of, the thickness, and the type of pests. For instance, materials can be kept in about 55-60 °C, -30 °C for up to a week or -20 °C for about two weeks. As for the relative humidity, most insects are able to survive and reproduce when it is above 70%. Some species such as clothes moths and carpet beetles, however, prefer dry environments. Low oxygen, high carbon dioxide environments can also be used to kill insects. Different species prefer different levels of light. Moreover, it can change their hibernation and breeding patterns. Since UV light tends to attract nocturnal insects, it is not recommended to be used as external lighting close to cultural institutions. It is also important to ensure that pests do not have enough food, such as food stains on textiles or wood of a certain moisture content. /1, p. 13-15, 7./

2.2 Hygrothermal requirements for cultural institutions in Lithuania

Generally, the comfort conditions are considered to be around 24,5 ± 1,5 °C and 40-60% during the warmer season. In the colder months, the temperature can be about 22 ± 2 °C and the relative humidity should remain similar. /8, p. 3, 9, p. 19./ These are the rough estimates of hygrothermal conditions in which people that are at rest should feel comfortable. Depending on other aspects such as age, physical activity, and clothes, these values change. The temperature and relative humidity in cultural institutions should be chosen taking into account the conditions the collections require as well as the comfort of the visitors or workers.

The “Instruction on Protection, Accounting, and Storage of Museum Collections”, issued by the Ministry of Culture of the Republic of Lithuania, presents the main aspects of indoor climate that are important when considering the preservation of collections. Moreover, it provides specific values that are the most suitable for different materials. Since this study was concerned with temperature and relative humidity specifically, the requirements related to these values will be presented.

As previously explained, depending on the material or materials an artefact is made of, the most suitable conditions for it will be different. Generally, paintings and similar work of art are the most sensitive to humidity and lack of light. Therefore, they should be stored in the premises that are dry and there is a sufficient amount of light. Fabrics are also sensitive to humidity. Exhibits made from ceramics, glass, and stone can be stored in darker, more humid premises. Colder but dry spaces are suitable for metal products. Tin artefacts, however, will be damaged by low temperatures. Therefore, they have to be stored in warm premises. Taxidermy mounts and furs should be kept in a dry environment, while the premises where exhibits from paper are kept should be dry and well ventilated. /2, p. 24./ As can be seen from these general requirements, different materials are not equally susceptible to damage caused by temperature or humidity. More specific requirements of indoor climate of storage and exhibition premises for different materials are also provided in the "Instruction on Protection, Accounting, and Storage of Museum Collections". They are presented in Table 1.

Table 1. Temperature and relative humidity requirements for different materials /2/

Material or type of object	**Temperature, °C**	**Relative humidity, %**
Paintings	16-18	40-60
Paper	12-18	50-60
Wood	18	50-60
Metal	15	30-40
Fabrics, leather	10-15	50-65
Zoological specimens	16-20	55-65
Photographic materials	< 5 / < 12	40-50
Plasticine, wax	16-25	-

Even though some materials require similar conditions, for others the indoor climate must be quite different. The ranges of temperature and relative humidity for paintings and paper products such as books, documents or maps, and wooden objects have some differences but overall it is possible to keep them in the same premises. /2, p. 24-25, p. 27./ Metal artefacts, however, require lower temperatures and a much lower relative humidity. Tin, for instance, is especially sensitive to low temperatures. Therefore, exhibits made from or containing tin parts should be kept in temperatures higher than 13,6 °C. If any damage is noticed, they should be moved to a warmer room of about +20 °C and a conservator should evaluate their state. /2, p. 28./ Fabrics and leather also require lower temperatures but the relative humidity is quite similar to that of paper and wood /2, p. 29/. In order to preserve zoological specimens, including but not limited to taxidermy mounts, furs, skeletons, wet specimens (animals or their parts conserved in liquids), the temperature and the humidity should also be closer to those suitable for preserving paintings, paper, and wood. All exhibits except the wet specimens are affected by big temperature or humidity changes regardless of whether they occur because of changing seasons or during shorter periods of time. Therefore, their condition should be constantly monitored, especially during the period from April until September, the hottest months of year. /2, p. 30-31./

Premises where geological and mineral exhibits are kept should not have sudden temperature or humidity changes /2, p. 31/. Botanical exhibits should be in premises where the relative humidity is not higher than 65% /2, p. 32/. Photographic materials should be kept in premises with 40-50% of relative humidity. The temperature for monochrome photographs should not be higher than 12 °C. For colour photographs, the limit of 5 °C should not be exceeded. If photographs are stored in the same premises as other types of exhibits, the temperature should not be higher than 20 °C and the relative humidity should not exceed 53%. Objects made from plasticine or wax are not as sensitive. The relative humidity is not specified. The temperature should be in the range from 16 °C to 25 °C. /2, p. 20./ As is evident from the requirements, the ideal conditions differ slightly depending on the materials an exhibit is made from.

Many museums, however, keep many different artefacts in the same premises. There are general requirements for premises where artefacts from various materials are being exhibited or stored. If artefacts from various materials are exhibited in the same premises, the temperature should be 18 ± 2 °C, the relative humidity – 55 ± 5%. The same requirements apply if such artefacts are stored in the same premises. Display cases with built-in humidifiers, for instance, are used to ensure that more sensitive artefacts or material with slightly different requirements remain in optimal conditions. If no air conditioners are installed in the exhibition rooms, the relative humidity can be in the range from 35% to 65%. The daily fluctuation of relative humidity should not be higher than 5%. /2, p. 20, p. 24./

As mentioned in the previous subsections, indoor climate has an influence on the biological factors, such as bacteria, mould, insects or rodents, that might negatively affect the artefacts. Therefore, when the temperature is in the range from 20 °C to 25 °C, the relative humidity cannot be higher than 70%. /2, p. 21./ If the temperature and relative humidity tend to fluctuate considerably in the storage spaces, some additional requirements should be considered. If the premises are too dry, they should be humidified. In the opposite case, when the air is too humid, a dehumidifier should be used. /2, p. 24./

2.3 Hygrothermal requirements for cultural institutions in Australia

In 2018, the Australian Institute for the Conservation of Cultural Material (AICCM) published updated indoor climate guidelines. Another version of the guidelines is the “Guidelines for Environmental Control in Cultural Institutions” published in 2002 by the Heritage Collections Council (HCC). Both of them are still in use, although the newer guidelines were created in order to expand the ranges set by the older version. /10./

Unlike the Lithuanian indoor climate guidelines for cultural institutions, the requirements in Australia depend on the region. There are six main climatic zones. The tropical zone is characterised by high temperatures throughout the year, very high humidity in the summer, also known as the wet season, and cooler nights during the short winter – the dry season. The winter days and nights in the subtropical zones tend to be mild to cool and cool to cold, respectively. The days during the summer are hot and humid while the nights are slightly cooler.

Hot arid climatic zones are characterised by very hot and dry summer days, warm to hot summer nights, warm to mild winter days, and cool to cold winter nights. Very hot dry summer days, hot to mild summer nights, mild to cold winter days, and cold winter nights are characteristic of warm dry temperate climatic zones. Temperate zones are characterised by warm to hot summers with moderate to high humidity, cool to cold winter days, and cold winter nights. In cool temperate zones, the summer days are mild, the nights are cool, the days and nights during the winter tend to be cold. However, the winter days are usually sunny. Canberra is located in a cool temperate zone. /1, p. 48-49, 10./

As mentioned previously, there are two guidelines of indoor climate in cultural institutions in Australia. As explained in the HCC guidelines, the generally accepted values used to be 20 ± 2 °C and 50 ± 3% of relative humidity. These ranges, however, did not take into account hot humid climatic zones. In countries with such areas, it is recommended to maintain the relative humidity of around 65% for mixed collections, if there is air circulation. The HCC guidelines aim to rectify this. It has been found that organic materials which have naturally acclimatised to a relative humidity of about 50%, have a low risk of getting damaged if the humidity fluctuation is 10% (about 40-60%). If the variation is 20% (30-70%), it is dangerous to some composite objects. Fluctuation of 40% (10-90%) is destructive to most organic objects. Converting these values to tropical climates where the normal acclimatisation point can be around 65% of relative humidity is difficult, since above 70% the risk mould growth increases. Nevertheless, these values can be used to determine the ranges that will ensure collections survive fairly well. /1, p. 16./ The recommended values of temperature and relative humidity according to the HCC guidelines are presented in Table 2.

Table 2. Guidelines of hygrothermal conditions of cultural institutions in Australia by HCC /1/

Climate type	Temperature range, °C	Relative humidity range, %
Hot humid	22-28	55-70
Hot dry	22-28	40-60
Temperate	18-24	45-65

As is evident from the information presented in Table 2, the requirements are divided into three categories depending on the climatic zone. Collections in hot humid and hot arid zones should be kept in the same temperature. The humidity, on the other hand, can be higher in humid zones. The temperature in temperate zones is usually a bit lower. The relative humidity is similar. It is recommended to keep the levels of temperature and relative humidity within the recommended ranges. If it is not possible, either the duration of high and low levels or the fluctuations should be reduced. /1, p. 16./ The guidelines published by AICCM set out to expand these recommended figures. They are presented in Table 3.

Table 3. Guidelines of hygrothermal conditions of cultural institutions in Australia by AICCM /10/

Climate type	Temperature range, °C	Relative humidity range, %	
Subtropical/Tropical	15-25	50-60 ± 5	
		Total range	45-65
Temperate	15-25	45-55 ± 5	
		Total range	40-60

Compared to the HCC guidelines, the temperature range suggested by the AICCM is much wider. The relative humidity ranges are presented in two ways. The first row shows the set range of humidity. This was done with energy efficiency in mind. Since changing the conditions to a range instead of a median point may require small and fewer corrections, this way of presenting the values was selected. The total ranges are presented for clarification and to show the minimum and maximum values. It is recommended, if possible, to maintain the humidity in the ranges of 50-60% and 45-55%, depending on the climatic zone. The total ranges take into account a short term 5% variation of a duration of less than 24 hours, which is acceptable. As for the temperature, less than 4 °C fluctuations for less than a day are also acceptable. /10./

As can be inferred from the chapters dealing with indoor climate requirements for cultural institutions in Lithuania and Australia, there are some differences between them. As mentioned previously, they differ because Australia has multiple different climatic zones. In addition, in the Lithuanian requirements more emphasis is placed on exact values and ranges. The Australian guidelines are focused more on the processes and principles of how different conditions affect materials and objects. Moreover, a lot more attention is paid to energy efficiency and consumption. The values in the Australian guidelines are not presented as strict limits and evaluating them based on specific situations is recommended. Using landscaping, building construction and shape in order to achieve more suitable indoor climate conditions and decrease the energy consumption of HVAC systems is encouraged.

2.4 HVAC and automation systems

In order to ensure the indoor climate in cultural institutions is suitable for the collections and people, heating, ventilation, and air conditioning systems are used. In addition, automation systems are used in order to make sure the systems maintain the necessary conditions, react to changes, and collect data. The main equipment and its working principles will be briefly presented in this chapter.

In cultural institutions, separate heating systems with devices such as radiators, convectors or underfloor heating systems, if installed, usually serve to raise the temperature to around the necessary one. In cultural institutions, such systems and devices are used when large amounts of heat are required, e.g. in countries that experience cold seasons. They do not play a significant role in ensuring the hygrothermal conditions remain as close as possible to the specified values. Since this study is concerned with precise values specified in the requirements and considerably slight deviations from them, the heating systems were not analysed thoroughly. Therefore, they were not discussed in this chapter.

Ventilation and air conditioning systems are used to reach the more specific values of temperature and humidity as well as supply fresh air and cool the premises during the warmer seasons. Ventilation systems in cultural institutions that serve exhibition halls or storage areas are usually mechanical. In these types of systems, the air is moved (supplied or exhaust) with the help of fans and not due to natural forces that might be caused by wind or temperature differences. There can be separate systems that supply the air to the premises and exhaust it from them. It is also quite common to have one system that supplies and exhausts the air. The main parts of these systems are the air handling unit (AHU), ducts, and air terminal devices. If the system only extracts the air, instead of the AHU there might be just a fan that will move the air out of the premises. /11, p. 205./

There are four main terms that are used to describe air that is involved in ventilation or air conditioning systems. Outdoor air is fresh air that is taken from the outside of the building. After it is prepared – cleaned, heated or cooled to the necessary temperature, humidified or dehumidified – it is called supply air. Extract air is removed from the premises. Exhaust air is the air that is released outside the building. Generally, outdoor air enters the AHU and is prepared. Then, it leaves the AHU, goes through the ducts, and then reaches the air terminal devices which supply it to the premises. When the air is extracted from the premises, it is either exhausted to the outside with the help of a fan, in the case of an exhaust system, or moved to the AHU where it can be used to heat up the outdoor air and then removed. /11, p. 204./

The AHU consists of different parts. Some of them, such as heating and cooling coils, heat recovery units, and humidifiers, are optional. As mentioned previously, the fan ensures the air moves. In an AHU, there is a supply fan that moves the outdoor air through the AHU and the supply air from the AHU and to the ductwork. The exhaust fan ensures the air is extracted from the premises, goes through the AHU (if it is a supply-exhaust system), and is released to the outside. /11, p. 221-225./

There are two main types of fans – axial and centrifugal. In axial fans, the air moves perpendicular to the blades. In centrifugal fans, the air moves parallel to the blades and curves around them. /11, p. 221-225./ Filters are installed in the AHU in order to clean the outdoor air. While the dampers prevent animals or other bigger objects such as trash from entering the AHU, filters stop smaller particles, pollen and dust. They are installed after the dampers in the supply side and exhaust sides of an AHU. /11, p. 261./

Heat recovery units are used to recover heat from the extracted air and use it to increase the temperature of the supply air. There are different types of heat recovery units. Plate heat exchangers are useful in situations when the extracted air is polluted or contaminated since there is almost no mixing of the supply and exhaust air in them. In rotary heat exchangers, along with the heat, the humidity is also retained. However, there is usually more mixing of the air. Run-around coil heat exchangers are not as common. They are suitable when the supply and exhaust systems are not close to each other. This situation can be found in old buildings which were built without heat recovery in mind, for instance. /11, p. 273-277./ In some AHUs, there can be a mixing section. It allows a part of extracted air to be directly mixed with the supply air. This can only be used if the extracted air is clean enough. After the heat recovery unit or the mixing section, if they are installed, the supply air might still not meet the requirements, depending on the types of premises it will be supplied to. If the temperature needs to be increased or decreased, heating or cooling coils are used. In AHUs, they are usually filled with water. The supply air is heated or cooled as it goes through them. /11, p. 271-272./

If the air is too dry, humidifiers are used. Mainly, there are steam and evaporative humidifiers. In steam humidifiers, the water is heated by an electric coil. It turns into steam which is released to humidify the air. The working principle of evaporative humidifiers is quite different. The supply air is blown through a porous, absorbent material which is kept wet. /11, p. 352-354./ Not as often, dehumidifiers are installed. In desiccant dehumidifiers, the air is blown through materials that are able to absorb humidity due to their porousness or chemical properties. /11, p. 357-359./ In order to minimise the noise, mostly created by fans and the moving air, silencers are installed. /11, p. 255-256./ The configurations of the AHUs of the investigated premises will be explained in the subsections that present the systems in each building.

Nowadays, most modern AHUs have automated control systems. Different devices of the same building are often connected to the same automation system. This is called a building management system (BMS). It can ensure that the devices operate according to the set parameters, such as pressure, temperature, and relative humidity, and the indoor climate in the premises remains within the allowed limits. Additionally, it can help decrease the energy consumption, gather data about the indoor climate in the premises, and show if there are any issues or damage in the systems. /11, p. 285, p. 399./

3 RESEARCH METHOD

As mentioned previously, temperature and relative humidity were analysed in three different buildings: the Cultural Heritage Centre, the Palace of the Grand Dukes of Lithuania, and the Canberra Museum and Gallery. The indoor climate regulations pertaining to cultural institutions in Lithuania and Australia were studied. The HVAC systems serving premises where artefacts are stored or exhibited were analysed. Following that, the temperature and relative humidity readings were compared to the requirements. Suggestions for improvement, based on the comparison of the systems or otherwise, were determined.

Two of the analysed buildings – the Cultural Heritage Centre and Palace of the Grand Dukes of Lithuania, are located in Vilnius, Lithuania. The last building, the Canberra Museum and Gallery, is in Canberra, Australia. The rough average temperatures throughout the year in Vilnius and Canberra can be found in Table 4.

Table 4. The average monthly temperatures /12, 13/

Location	Monthly average temperature, °C											
	January	February	March	April	May	June	July	August	September	October	November	December
Vilnius, Lithuania	-6,4	-5,2	-0,9	5,5	12,3	15,6	16,7	16,0	11,3	6,3	0,9	-3,2
Canberra, Australia	21,0	20,0	18,0	14,0	10,0	7,0	6,0	7,0	10,0	13,0	16,0	19,0

As can be clearly seen from the average monthly temperatures (Table 4), the climate in Vilnius and Canberra is not similar. Since the data received from cultural institutions were limited, it was not possible to choose months during which the temperatures in both cities would be similar. Additionally, the amount of data that is analysed was reduced by choosing only a few months. Moreover, there are various types of premises in the analysed buildings, such as offices and restaurants. Only the rooms in which artefacts are stored or exhibited were chosen to be investigated. In order to ensure there was not too much information, only a few premises and systems were chosen from the buildings that had many of them. The reasons behind the choices will be explained further in the subsections that present the selected systems.

As a result, the measurements from February to March 2019 as well as February 2020 in the Cultural Heritage Centre were selected. The hygrothermal readings during March 2020 were selected for the Palace of the Grand Dukes. Measurements of the period from February to March 2020 in the Canberra Museum and Gallery were evaluated. The specific average monthly temperatures during the selected months can be found in Table 5.

Table 5. The average monthly temperatures in Lithuania and Australia during the selected months /14, 15/

Location	**Average monthly temperature, °C**			
	2019		**2020**	
	February	**March**	**February**	**March**
Vilnius, Lithuania	0,5-1	3-3,5	1,5-2	3-3,5
Canberra, Australia	18-21	18-21	18-21	15-18

Since the hygrothermal conditions in the cultural institutions were evaluated during the same part of the year, it is important to keep in mind that the climate in Australia is very different from Lithuania. Therefore, this study does not show which museum, or its HVAC systems, is better, at least during the chosen period. While the archive and museum in Vilnius can be compared this way, the systems in the museum in Canberra deal with very different outdoor conditions. Even with these differences, however, the comparison of HVAC systems, in a more general sense, is possible.

4 GENERAL INFORMATION ABOUT THE BUILDINGS AND THE SYSTEMS

4.1 Cultural Heritage Centre

Figure 1. The Cultural Heritage Centre /16/

The Cultural Heritage Centre collects data about cultural heritage necessary for inventory and maintains the cultural heritage inventory. It is also responsible for the collection and management of documents and data about cultural heritage. The Centre is located in Šnipiškių g. 3 Vilnius, Lithuania. The building itself was built in the 18th century. It is part of the Church of St. Raphael the Archangel and Jesuit monastery ensemble. The Department of Cultural Heritage of Lithuania and the Cultural Heritage Centre storage are in the premises of the former monastery. /17./ In this thesis, only the premises in which artefacts are exhibited or stored are considered. Therefore, only the Cultural Heritage Centre storage (archive) was investigated.

4.1.1 Systems

The area of the storage is 178,36 m^2. The systems in the archive are designed so that the indoor temperature should be 16 ± 2 °C and the relative humidity – 50 ± 5%.

The current indoor climate systems in the storage have been in the building since 2004. For convenience and security reasons, they were renamed. The systems are presented in Table 6.

Table 6. General information about the ventilation systems of the Cultural Heritage Centre archive

System	Supply air flow		Extract air flow	
	m^3/h	l/s	m^3/h	l/s
AHU-1.1	235	65,3	-	-
Extract	-	-	2820	783,3

The AHU-1.1 Amalva OTK-2-2/2-EU5-EK6-M-P-X-H is located in a separate technical room next to the archive. It supplies 235 m^3/h of air. The outdoor air enters the AHU-1.1 through the dampers. It is cleaned in the filter and then heated by an electrical heating coil. The fan helps to move the air further. It goes through the silencer before leaving AHU-1.1.

The air from the AHU-1.1 is supplied to a different technical room where a vertical floor mounted air conditioner unit STULZ CCU121A is located. The supply air from the AHU-1.1 together with the recirculated air in the room enters the air conditioner.

The air conditioner has the total cooling capacity of 12,4 kW. The refrigerant used is R407C. The air conditioner consists of a fan, a steam humidifier, two electrical heating coils of 6 kW and 4 kW heating power, a filter, a scroll type compressor, and an evaporator. The air-cooled condenser is on the wall outside the building. There is no separate heating system. The air conditioner heats the archive when needed.

The air to the air conditioner is supplied from the side and leaves it from the top after being prepared. The fresh air together with the recirculated air is then supplied to the archive. The air from the air conditioner goes through an additional filter before being supplied to the archive through grilles. The precise climate control conditioner ensures that the temperature in the archive is about 16 °C and the relative humidity is around 50%.

The smoke and air after a fire are extracted from the archive by a separate system that consists of ducts and a fan. It can extract up to 2820 m^3/h.

4.2 The National Museum – Palace of the Grand Dukes of Lithuania

Figure 2. An exhibition hall in the National Museum – Palace of the Grand Dukes of Lithuania /18/

The National Museum – Palace of the Grand Dukes of Lithuania is a museum located in a reconstructed historical residence. It has exhibitions presenting the development of the site, the stylistic development of the residence through the Late Gothic, Renaissance, and Early Baroque epochs. Visitors can see authentic walls from various periods as well as various exhibits – furniture, tapestries, paintings, maps, and weapons. The museum was founded in 2009. It is located in Katedros a. 4 Vilnius, Lithuania. /18./ The building is very big, there are different premises (offices, a restaurant, halls for events). Four exhibition halls were chosen to be investigated.

4.2.1 Systems

Due to security reasons, it was not possible to gain access to building plans that have the measurements of the premises in them. Therefore, the areas of the exhibition halls are unknown. It is known that the exhibition halls 1 and 2 are in the west wing, halls 3 and 4 are in the north wing of the building.

The systems are designed to ensure that the temperature in the exhibition halls is 18 ± 2 °C and the relative humidity is 50 ± 5%.

The four chosen exhibition halls are served by three different AHUs. As in the previous building, the systems and the premises were renamed for security and convenience reasons in the Palace as well. The AHU-2.1 serves three exhibition halls. In order to limit the amount of information, only two of these halls were chosen to be evaluated in the thesis. The other two exhibition halls are served by separate AHUs with the same configuration. The basic information about these systems is presented in Table 7.

Table 7. General information about the ventilation systems in the Palace of the Grand Dukes of Lithuania

<table>
<tr><th rowspan="2">System</th><th rowspan="2">Premises</th><th colspan="2">Supply air flow</th><th colspan="2">Extract air flow</th></tr>
<tr><th>m^3/h</th><th>l/s</th><th>m^3/h</th><th>l/s</th></tr>
<tr><td rowspan="2">AHU-2.1</td><td>Exhibition hall 1</td><td rowspan="2">3690</td><td rowspan="2">1025</td><td rowspan="2">3690</td><td rowspan="2">1025</td></tr>
<tr><td>Exhibition hall 2</td></tr>
<tr><td>AHU-2.2</td><td>Exhibition hall 3</td><td>7200</td><td>2000</td><td>6400</td><td>1777,8</td></tr>
<tr><td>AHU-2.3</td><td>Exhibition hall 4</td><td>7200</td><td>2000</td><td>6400</td><td>1777,8</td></tr>
</table>

The values of supply and extract air flows are known for the entire AHU-2.1 (three halls), even though only two exhibition halls were investigated. As can be seen from the differences of supply and extract air flow values, the sizes of the halls 3 and 4 are much larger. In order to ensure that the measured temperature and relative humidity reflect the real conditions in the rooms, two sensors are installed in different sides of these exhibition halls.

The exhibition halls in the museum are heated by fan coil units. Air is heated by being blown through heating coils inside the fan coils. They are installed under the windows.

Fresh air from the outside enters the AHU-2.1 through a damper section. It goes through a filter and a rotary heat exchanger. There, it is heated by the extracted air. Then the air goes through heating and cooling coils where it is heated up or cooled down depending on what is necessary at the time. There is also an additional heating coil that can be used when needed. After the air reaches the required temperature, it goes through a silencer and is supplied to a duct. Before the air reaches the air terminal devices in the premises, however, it is humidified. The duct from the AHU splits in two – one is for the exhibition hall 1, the other is for the hall 2 and another hall that was not evaluated in this study. For this reason, there are two separate humidifiers in these ducts.

Extracted air enters the AHU by going through a silencer. It is cleaned in a filter before entering the rotary heat exchanger. There, it gives up its heat to the outdoor air. After that, it is either released outside the building or a part of it is added to the outdoor air and enters the AHU once again. There is no mixing section in the AHU itself, however. The air is either exhausted to the outside or leaves the AHU through a duct. It is connected to another duct through which the outdoor air reaches the AHU.

AHU-2.2 and AHU-2.3 have the same configuration. Similarly to the previous one, the outdoor air enters the AHU, is cleaned, and heated in a rotary heat exchanger. There is a mixing chamber that allows the extracted air to mix with the outdoor air. Following that, the air is heated or cooled in the heating and cooling coils. After this temperature change, the air is humidified and heated once again. It leaves the AHU after passing through a silencer.

The extracted air goes through a silencer and is cleaned after that. Then, some of it might enter the mixing chamber. If it doesn't, it passes through the rotary heat exchanger and, after giving up its heat, is exhausted from the building.

4.3 Canberra Museum and Gallery

Figure 3. A gallery in the Canberra Museum and Gallery /19/

The Canberra Museum and Gallery is, as the name suggests, an art gallery and museum. According to one of the workers of the Gallery, the building was built in the 1970s. It is located in 176 London Circuit, Canberra, Australia. Paintings, ceramics, photographs, and other works of art are exhibited there. The themes of the exhibitions are mostly related to the history, social issues, and peculiarities of Canberra and Australia. The Canberra Museum and Gallery was opened in 1998. /20, 21./ As in the previously presented cultural institutions, only the premises in which artefacts are exhibited or stored were evaluated. Two premises were chosen.

4.3.1 Systems

The temperature in the premises where collections are stored or exhibited are designed to be 22 ± 1,5 °C and the relative humidity – 50 ± 5%. The site had an upgrade of HVAC systems in 2017-2018.

A gallery and a gallery repository were investigated. The systems were renamed for convenience and security reasons. They are served by two separate AHUs. The AHUs are located on the first floor while the premises they supply the air to are on the ground floor. The basic information about the systems is presented in Table 8.

Table 8. The general information about the ventilation systems in the Canberra Museum and Gallery

System	Premises	Supply air flow		Extract air flow	
		m^3/h	l/s	m^3/h	l/s
AHU-3.1	Gallery	7920	2200	-	-
AHU-3.2	Gallery repository	5400	1500	-	-
Extract	Gallery	-	-	7920	2200
Extract	Gallery repository	-	-	5400	1500

The gallery is served by GJWALKER ASH 23, the gallery repository – by GJWALKER ASH 18. Both of these AHUs have the same parts but their sizes, air flows, fans, cooling and heating coil capacities are different.

Outdoor air enters the AHU through a damper section and is cleaned in the filter. Then, it is heated or cooled by the heating and cooling coils. Following that, the air is humidified or dehumidified. AHU-3.1 and AHU-3.2 share a common desiccant dehumidifier unit. Prepared supply air leaves the AHU by going through a silencer. Unlike the AHUs in the Palace of the Grand Dukes of Lithuania, the AHUs in the Canberra Museum and Gallery do not have heat recovery units. The air is exhausted by separate systems that consist of a fan and ductwork.

It was possible to acquire more information about the building management system (BMS) and its operating principles in regards to the AHUs. The supply air is humidified when the relative humidity in the room is less than the humidity setpoint (50%) for a period of 5 minutes. This process stops when the relative humidity remains 5% greater than the setpoint for 5 minutes. The same conditions – 5% and a period of 5 minutes – apply for the dehumidification process, as well. The BMS is capable of generating system alarms. For instance, a dirty filter alarm is turned on according to the readings of a differential pressure sensor across the filter. If the pressure exceeds 20 Pa at a 10% AHU fan speed and 125 Pa at 100% fan speed, with a linear relationship between these limits, the dirty filter alarm is generated.

In addition, the BMS has different modes of operation that can be enabled. Typically, both AHUs are turned on continuously, 24 hours a day, 7 days a week. During occupied hours, when the museum is open to visitors, the supply fans are switched on at full speed. It is possible to enable the BMS to decrease the fan speed to 50% when the Gallery is unoccupied. This value of 50% can be adjusted. There is also an economy cycle mode that is initiated when the outside air condition is suitable. The outside air temperature must be below 24 °C, the extracted air temperature must be greater than the outdoor temperature, and the relative humidity must be between the humidification and dehumidification setpoints, which are adjustable.

5 RESULTS

5.1 Cultural Heritage Centre archive

Since the devices in the Cultural Heritage Centre are not very new, there is no automation that would ensure that measurements of temperature and humidity are constantly taken. The responsible employees check these values every few days. The measurements taken during February and March 2019 as well as February 2020 are evaluated in this chapter.

As can be seen in Figure 4, the measurements were only taken three times during February 2019.

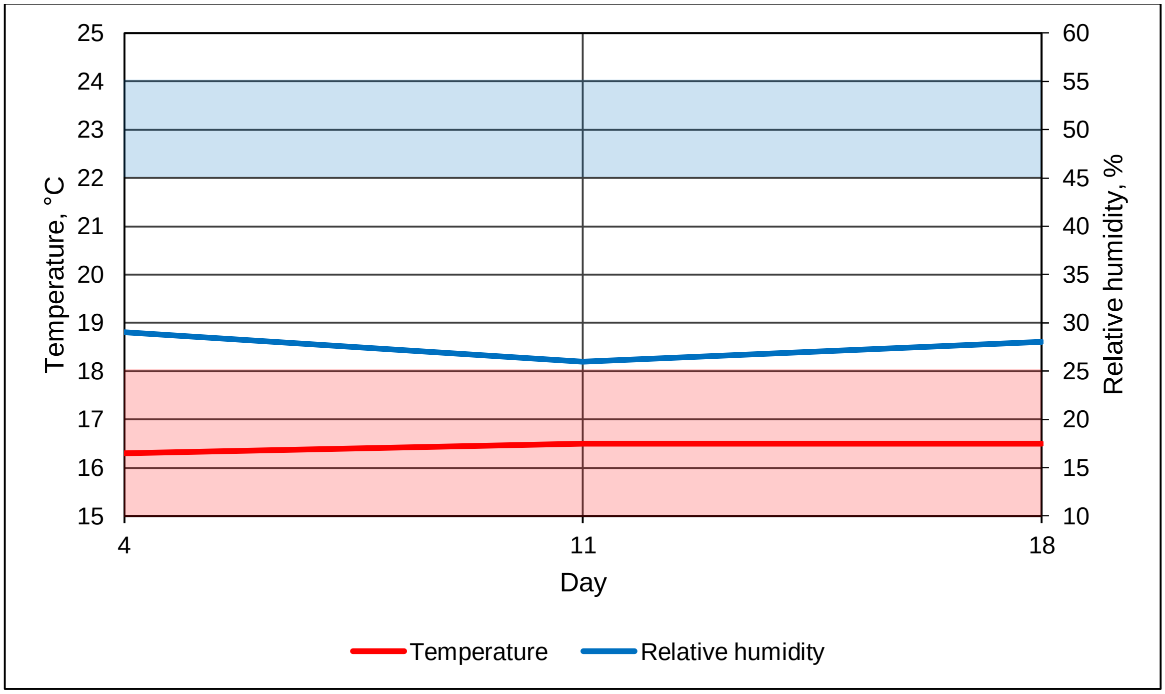

Figure 4. The temperature and relative humidity measurements in February 2019

The average temperature was 16,4 °C, the relative humidity – 28%. As mentioned in the subsection about the systems in the Centre, the temperature should be between 14 °C and 18 °C. During this month, at the times the measurements were taken, the values remained between 16 °C and 17 °C. Therefore, the temperature requirements were met. The relative humidity should remain around 45-55%. As shown in Figure 4, it was in the range from 25% to 30%.

As shown in Figure 5, the measurements of hygrothermal conditions were recorded four times during March 2019.

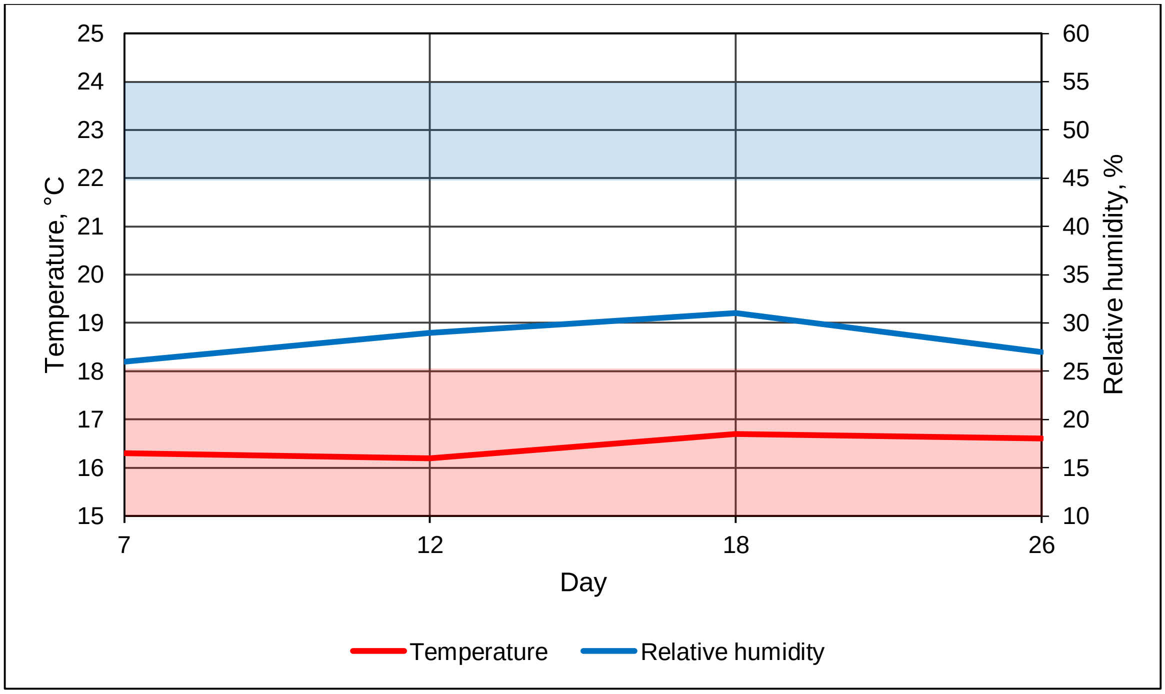

Figure 5. The temperature and relative humidity measurements in March 2019

On average, there were 28% of relative humidity and 16,5 °C. The temperature stayed in the same range as during the previous month – between 16 °C and 17 °C. The relative humidity, however, was once again too low. It ranged between around 25% and 31%.

As seen from Figure 6, in February 2020 the values of temperature and humidity were checked four times.

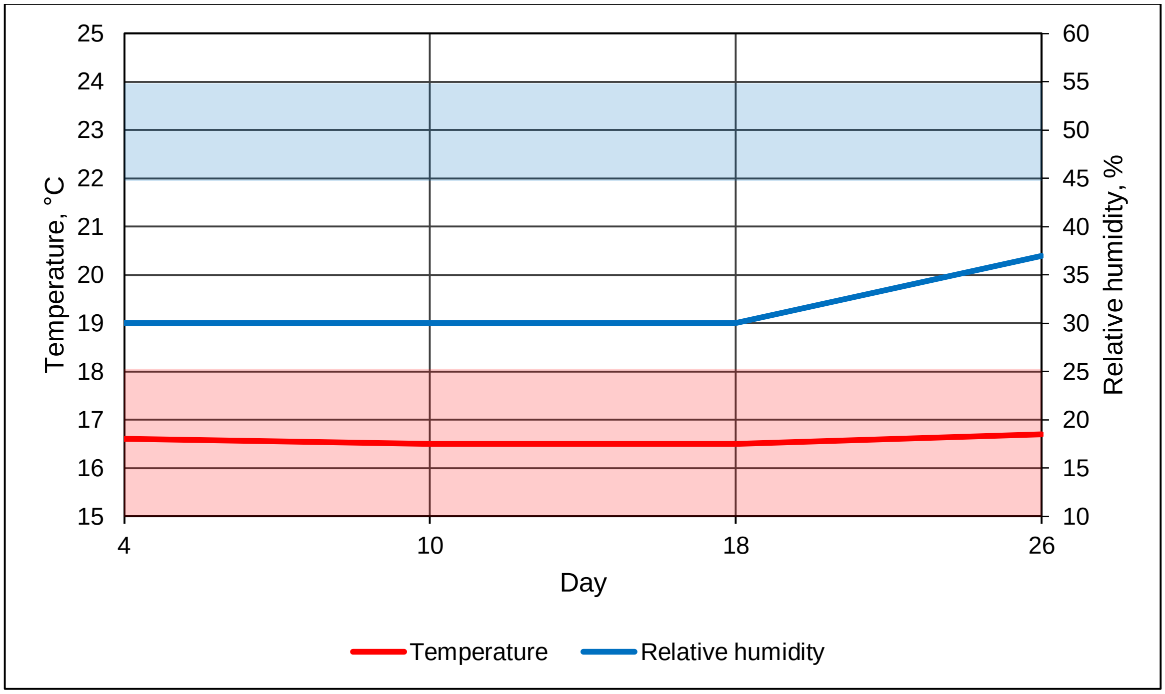

Figure 6. The temperature and relative humidity measurements in February 2020

The average temperature was 16,6 °C and the relative humidity was 32%. As in the selected months during the previous year (Figures 4 and 5), the temperature once again remained between 16 °C and 17 °C. The relative humidity was 30%, except for the last measurement of the month when it was about 37%. Even though this value was a bit higher, it still did not reach the minimum required value of 45%.

During the selected months, the humidity never reached even the minimum required value. This begs the question of whether this problem only occurs during this part of the year or is it an all-year round problem. Since the temperature and relative humidity measurement values throughout the entire year of both 2018 and 2019 were possible to acquire, they were also analysed.

It is clear to see from Figure 7 that the relative humidity values during 2018 only reached or rose above the required minimum in the summer and early autumn.

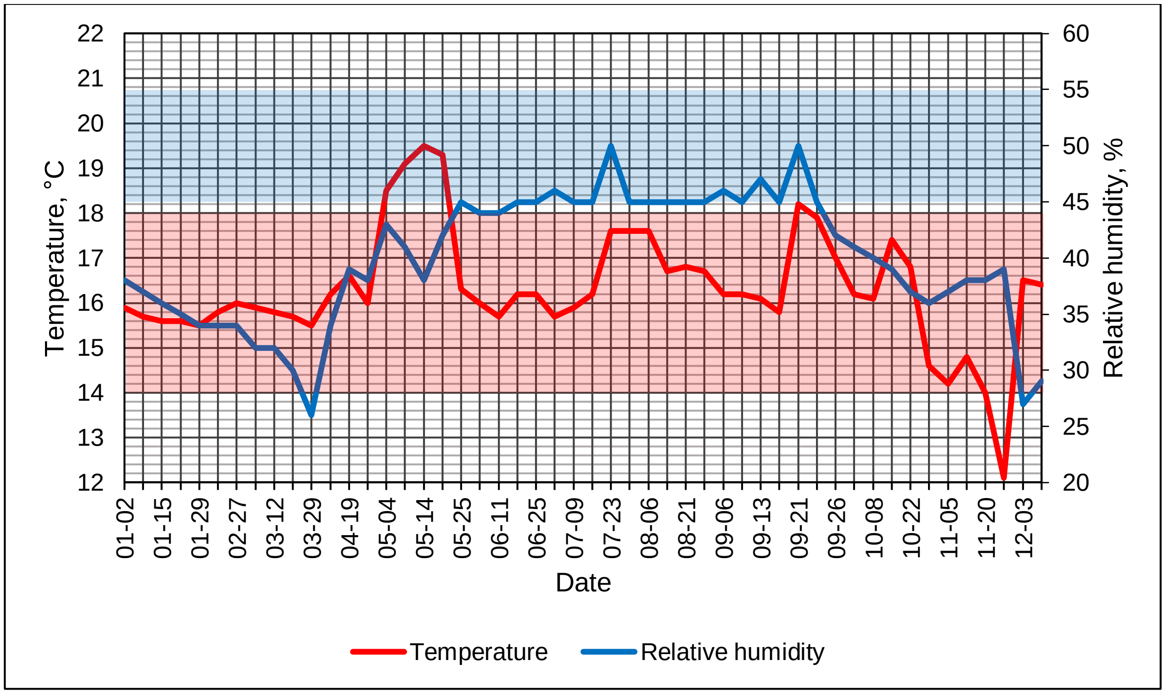

Figure 7. The temperature and relative humidity measurements in 2018

The average values were 40% of relative humidity and 16,3 °C. The relative humidity at the lowest point, in March, was only about 26%. Another problem that was not seen in the previously analysed months is the temperature. Not only did the minimum and maximum values differ rather significantly but they also did not fit into the limits from 14 °C to 18 °C. The lowest value was observed to be about 12 °C in December, the maximum was around 19.5 °C in May. The temperatures were above the maximum temperature limit in May and once in September.

As can be seen from Figure 8, the average temperature in 2019 was 17,8 °C, the relative humidity was 34%.

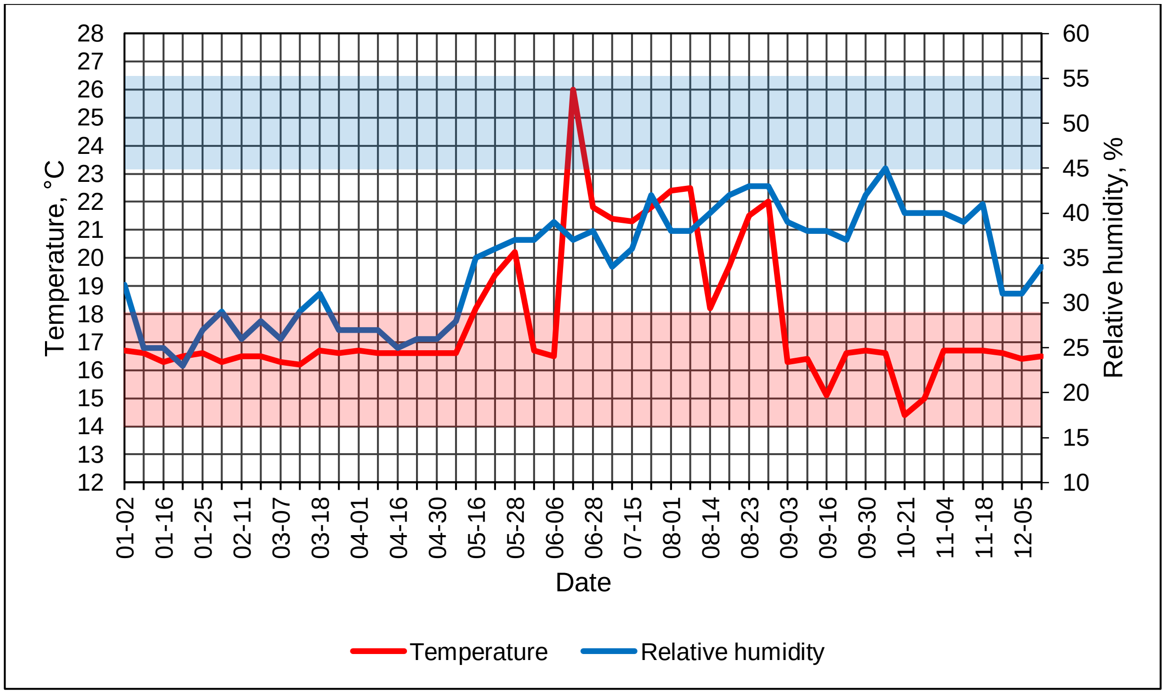

Figure 8. The temperature and relative humidity measurements in 2019

The minimum value of relative humidity (45%) was only recorded once, in October. Throughout the rest of the year the humidity remained below the minimum, going down as low as around 23% in January. The recorded temperature values exceeded the 18 °C limit in the late spring and during the summer.

It is clear to see from the figures depicting the recorded values during the year 2018 and 2019 that the problem of the relative humidity being too low persists throughout the entire year (Figures 7 and 8). The values only increased and came closer to the minimum limit in the second half of summer and in early autumn. According to one of the workers in the archive, initially the system worked as it should. However, during some construction work later on, the flow in the pipe that should have supplied the water to the humidifier was obstructed or cut off. Supposedly, there were ideas to connect the humidifier to the pipes of the system that is used in case of a fire. It is unclear whether this was ever implemented but based on the relative humidity readings it appears to not have been done.

The temperature seems to remain within the limits during all seasons except in late spring and summer. The recorded temperatures were very stable during the beginnings of both years. It appears that if the weather outside becomes too hot, the system does not manage to cool down the archive enough for the temperature to remain below the maximum limit. The temperature dropped in autumn and winter during both years. The temperature was too low only once, in December 2018. From the recorded values, there does not seem to be a serious problem with lack of heating. That one day might have been very cold and the outside temperature exceeded the design temperature which was -23 °C.

It is important to note that the fluctuations of relative humidity should not exceed 5% during 24 hours. In the current situation, when the measurements are taken every few days, there is no possibility to confirm that this requirement is met.

5.2 The National Museum – Palace of the Grand Dukes of Lithuania

The temperature and relative humidity readings in Palace of the Grand Dukes of Lithuania are taken every five minutes. The measurements recorded in four exhibition halls in March 2020 are presented in this chapter.

In the exhibition hall 1, there is one sensor. Its measurements are presented in Figure 9.

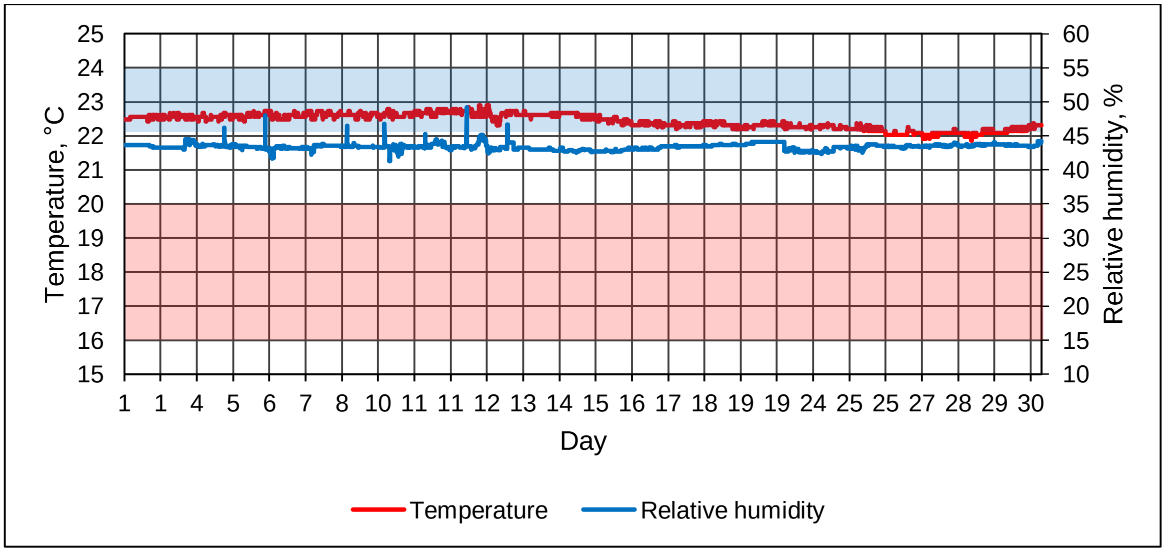

Figure 9. The temperature and relative humidity measurements in the exhibition hall 1

The average values of 22,4 °C and 44% of relative humidity were recorded. The temperature throughout the month remained in the range from about 21,8 °C to almost 23 °C. According to the design documents, the systems were designed so that the temperature should not rise above 20 °C. The relative humidity remained in the range from around 43% to 45% most of the time. The lowest point was about 41% and the highest values that were reached were around 49%. According to the design documents, the relative humidity should be 50 ± 5%. Therefore, the temperature was too high and the relative humidity was a bit too low. It is possible that the requirements for this particular exhibition hall were changed after the museum was built and the exhibits were placed. For instance, some halls in the Palace have paintings. Referring back to the Lithuanian requirements, the relative humidity as low as 40% is suitable for them. Some exhibits are placed in display cases which have built-in humidifiers so that their specific needs can be met. Another possibility is the placement of the sensor. According to one of the workers in the museum, some sensors are placed in the corners of the premises or there is furniture or exhibits between the sensor and the air in the exhibition hall. In some exhibition halls, the lighting close to the sensors might interfere with the temperature measurements. Consequently, the readings of the sensors might not reflect the actual conditions in the premises.

There is one sensor in the exhibition hall 2, as well. The recorded hygrothermal conditions are presented in Figure 10.

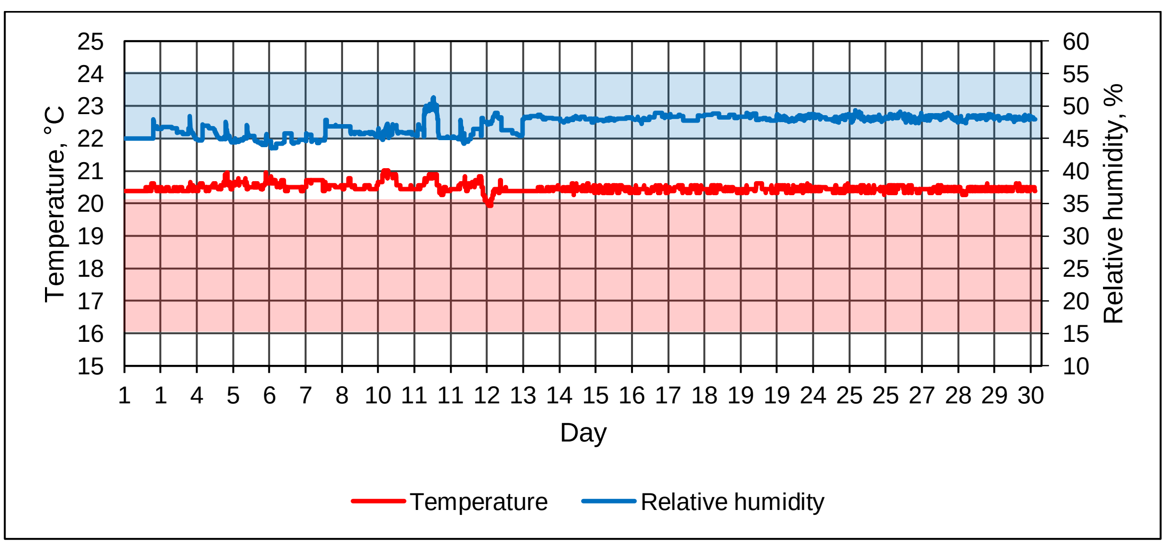

Figure 10. The temperature and relative humidity measurements in the exhibition hall 2

According to the readings of the sensor, the average temperature was 20,4 °C, the relative humidity – 46%. The temperature was between 19,9 °C and 21 °C. The relative humidity fluctuated between 44% and 52%. For the most part, it remained about 45-48%. As opposed to the exhibition hall 1, this one was much closer to meeting the requirements of relative humidity. The temperature, however, was still a bit too high. The same reasons as in the previous hall are possible.

As stated in the subsection containing the information about the systems, there are two sensors in the exhibition hall 3. As can be seen from figures 11 and 12, there are slight differences in the readings of both sensors.

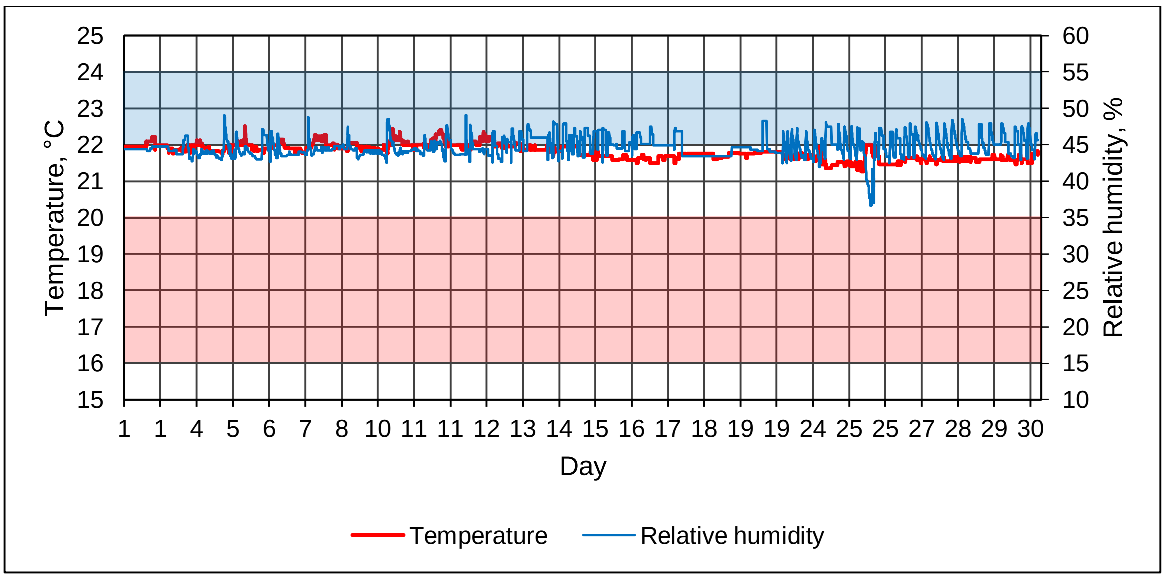

Figure 11. The temperature and relative humidity measurements of the first sensor in the exhibition hall 3

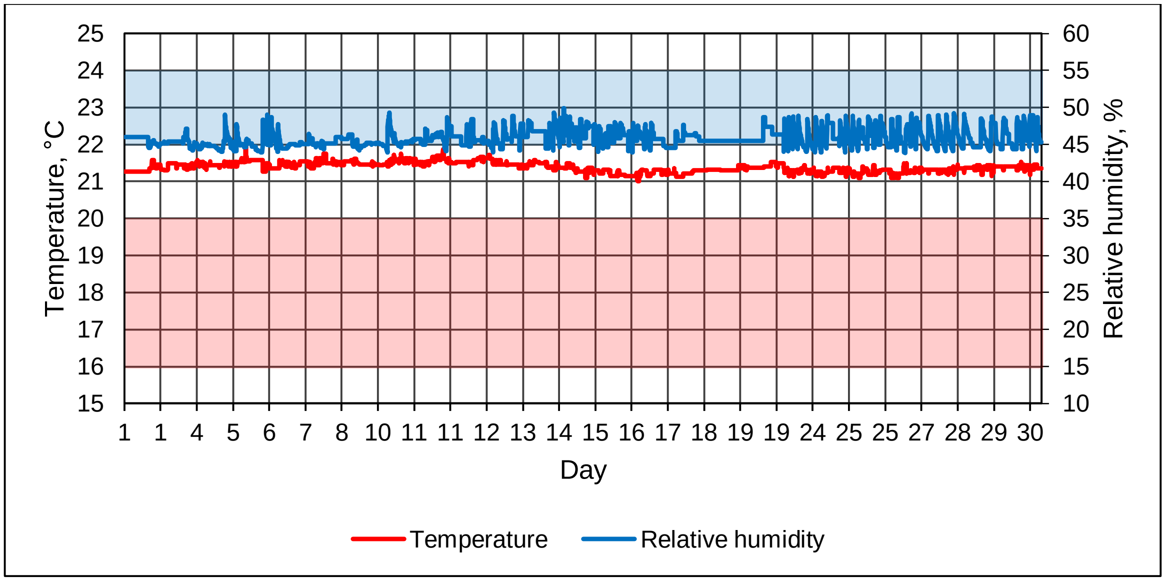

Figure 12. The temperature and relative humidity measurements of the second sensor in the exhibition hall 3

According to the readings of the first sensor, the average temperature was 21,8 °C. Most of the time, it was in the range from about 21,5 °C to about 22,5 °C. On average, there was 45% of relative humidity. The relative humidity was between 43% and 48% for the most part. The lowest point was around 36%. Based on the readings of the second sensor, the average temperature was 21,3 °C, the relative humidity – 46%. The values ranged from 21 °C to 22 °C, the relative humidity – from 44% to 49%. Generally, both sensors showed similar results. As in both previous exhibition halls, the temperature is above 20 °C. The relative humidity almost meets the requirements.

As in the previous hall, there are two sensors in the exhibition hall 4. The recorded values are presented in Figures 13 and 14.

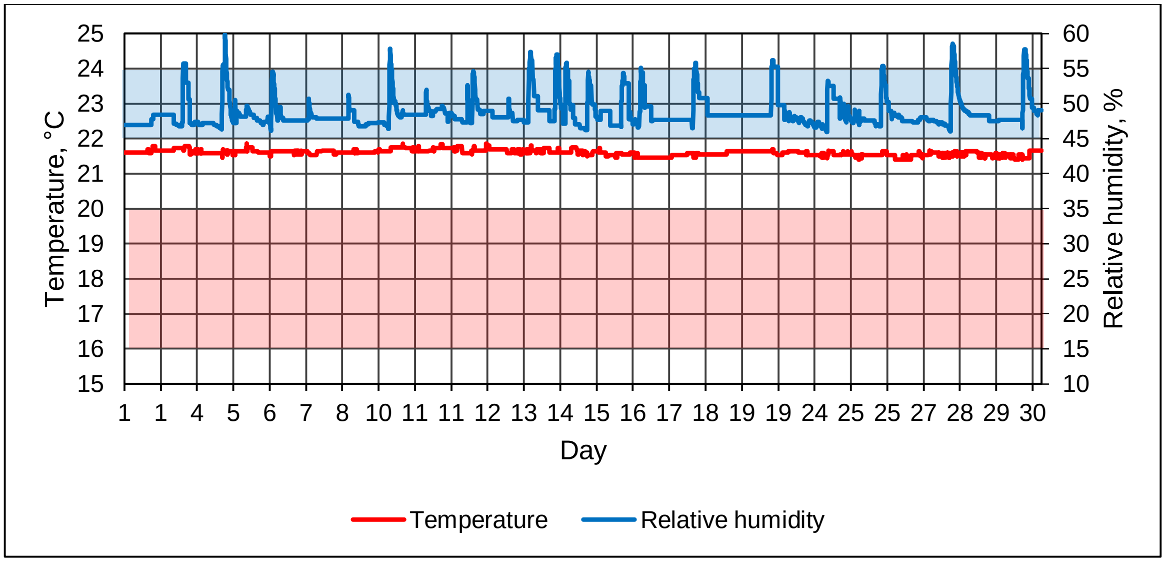

Figure 13. The temperature and relative humidity measurements of the first sensor in the exhibition hall 4

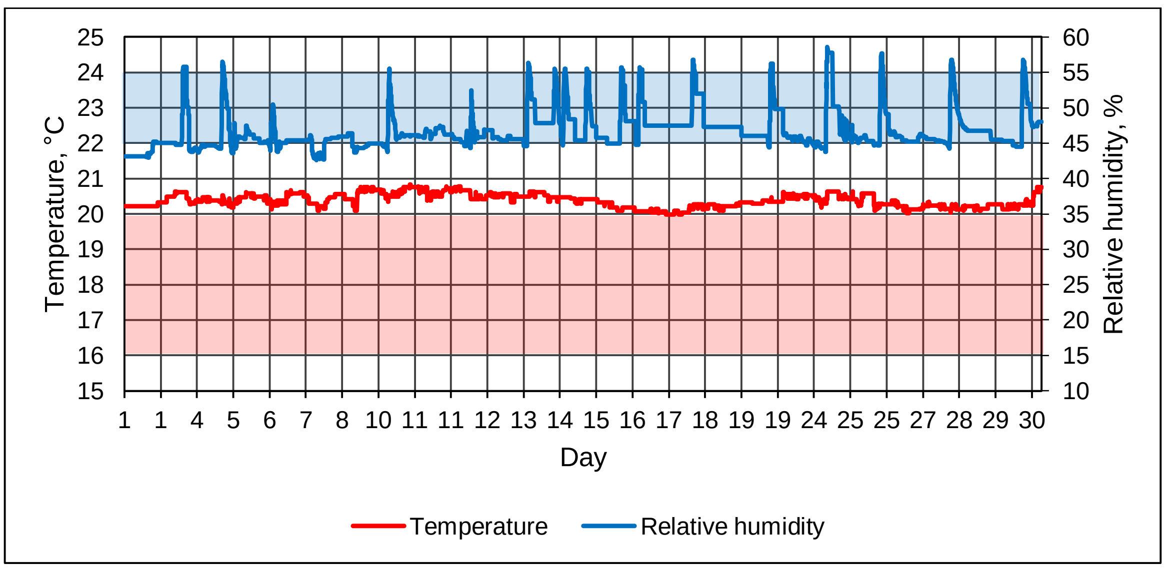

Figure 14. The temperature and relative humidity measurements of the second sensor in the exhibition hall 4

The readings of the first sensor show that the temperature was in the range from 21,4 °C to 21,9 °C. Its average value was 21,6 °C. The relative humidity, on the other hand, did not remain very stable. On average, it was 48%. However, the values were between 46% and 60%. The second sensor recorded the average temperature of 20,5 °C and the relative humidity of 46%. The values ranged from 20 °C up to 21,8 °C and from 43% up to 58% of relative humidity. Once again, the temperature readings showed them to be above the upper limit of 20 °C. As can be clearly seen just from looking at the figures 10 and 11, the relative humidity fluctuated a lot more than in the other exhibition halls.

Overall, the temperature seemed to be maintained at rather constant values in the exhibition halls 1, 2, and 3. The values were different from the requirements, though. The average values should be 18 °C and 50%. According to the measurements of the conditions in the halls, the average values for the temperature are 22,4 °C in the first hall, 20,4 °C in the second hall, 21,6 °C in the third and 21,1 °C in the fourth exhibition halls. Therefore, it seems reasonable to assume that they were specifically set to different values than the ones specified in the design documents because of the types of exhibits in the exhibition halls. However, since the air is supplied by the same AHU to the exhibition halls 1 and 2, their recorded temperature values should be very similar.

As for the relative humidity, instead of 50%, the average values are 44% for the first, 46% for the second and third, and 47% for the fourth exhibition hall. Referring back to the subsection that introduces the systems of the Palace, exhibition halls 1 and 2 are served by the same AHU but humidifiers are installed in the ducts for both halls separately. As humidity increases, the temperature drops. That would explain why in the exhibition hall 1 the temperature is higher and the relative humidity is lower compared to the exhibition hall 2.

As specified in the “Instruction on Protection, Accounting, and Storage of Museum Collections”, the relative humidity fluctuation should not be higher than 5% in 24 hours. In the exhibition hall 1, this limit was exceeded once, on 12th March. In the second hall, it was exceeded on 11th of March. However, the variations in both of these premises seem to be about 5% and not higher. Moreover, this occurs only once. Along with the fact that the sensors might be installed in places where their readings are not extremely accurate, these fluctuations do not appear to be a serious issue. In order to be able to determine whether this problem persists, the measurements during the entire year should be checked. It was not possible to acquire them for this study, so no firm conclusions can be made regarding these variations.

The fluctuations of relative humidity in the exhibition halls 3 and 4 appear to be much more frequent. Based on the readings of both sensors in the exhibition hall 3, the variation of around 4% is almost constant. While this does not exceed the limit of 5%, it is concerning because of its consistency. As for the exhibition hall 4, the fluctuation of about 10% occurs periodically throughout the entire month. It is unclear what might be causing such severe changes. It should be noted that the temperature in both of these exhibition halls seems to remain stable. There is a possibility that the humidifiers are configured incorrectly and that results in a delay. Because of that, the relative humidity of the supply air is increased too much and the process stops only when the humidity is already too high. As in the previous exhibition halls, the placement of the sensors might not reflect the actual situation in the premises.

All in all, there seem to be differences between the design values and the real conditions in the exhibition halls. The relative humidity in two exhibition halls appears to fluctuate rather significantly. In order to find out whether there are issues concerning the temperature and relative humidity, the readings throughout the entire year should be analysed.

5.3 Canberra Museum and Gallery

Much like in the Palace of the Grand Dukes of Lithuania, the temperature and relative humidity measurements are recorded every five minutes in the Canberra Museum and Gallery. In this study, the readings of a gallery and a gallery repository in February and March 2020 will be evaluated.

The measurements in the gallery during February 2020 are presented in Figure 15.

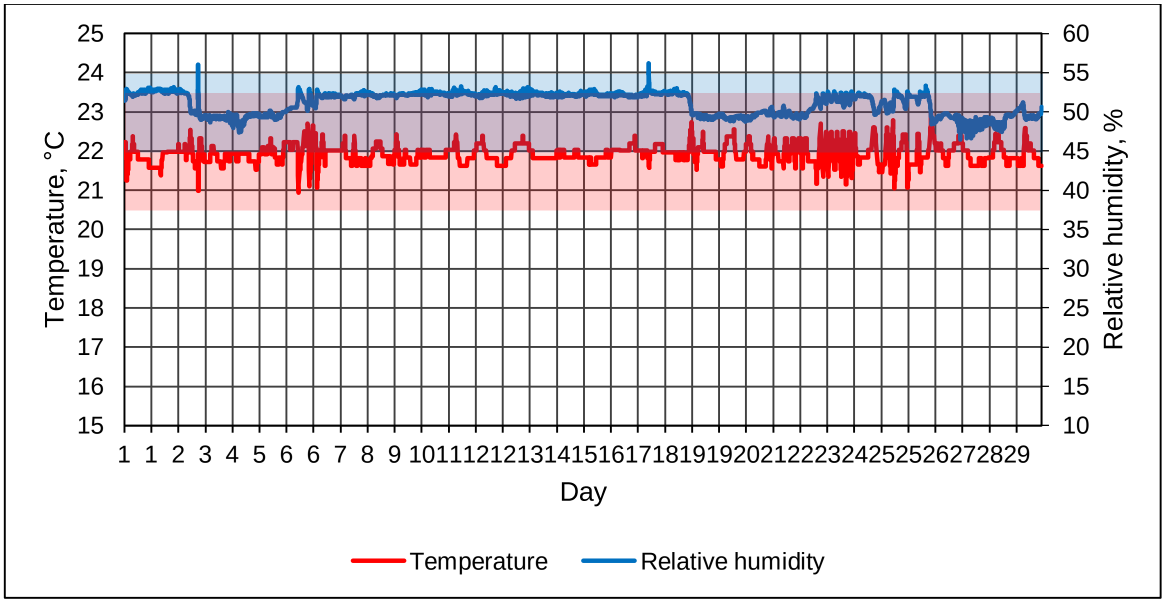

Figure 15. The temperature and relative humidity measurements in the gallery in February 2020

According to the readings from the sensor in the gallery, the temperature varied from around 20,9 °C to 22,8 °C. On average, it was 21,8 °C. The relative humidity average value was 51%. The lowest point was around 47% of relative humidity while the highest value was 56%. As stated before, the design values were 22 ± 1,5 °C and 50 ± 5% of relative humidity. Based on the measurements during February 2020, these requirements were mostly met.

The readings in the gallery during March 2020 are shown in Figure 16.

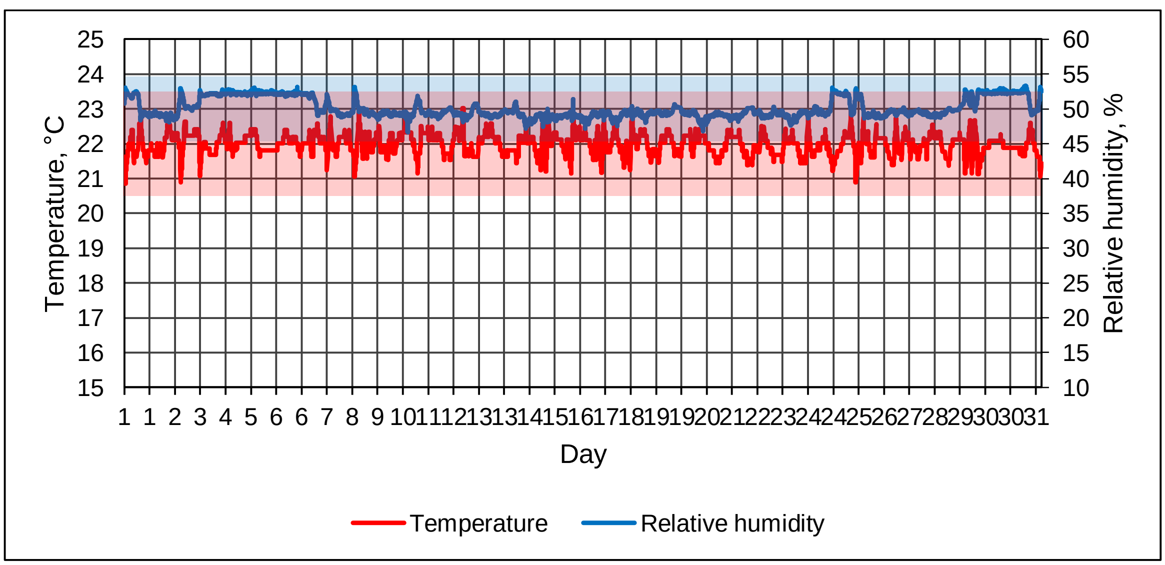

Figure 16. The temperature and relative humidity measurements in the gallery in March 2020

The temperature varied between 20,9 °C and 22,9 °C. Its average value was 21,5 °C. The relative humidity was in the range from 47% to 54%, the average value was 52%. Once again, the hygrothermal conditions remained within the limits.

The values recorded in the gallery repository during February 2020 are presented in Figure 17.

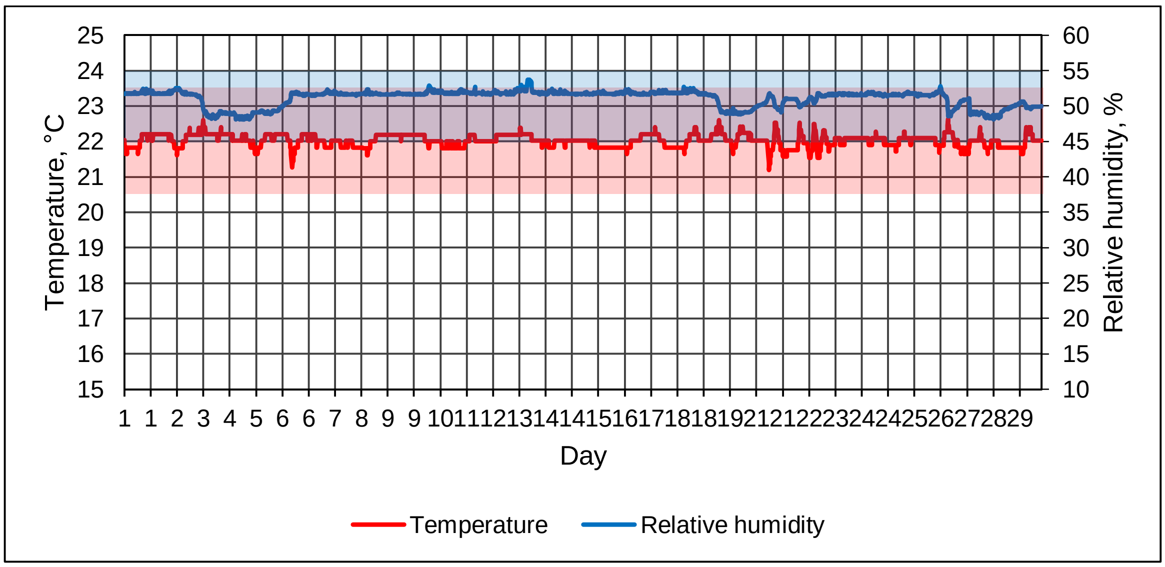

Figure 17. The temperature and relative humidity measurements in the gallery repository in February 2020

The average values were 22 °C and 51% of relative humidity. The temperature ranged from around 21,1 °C at the lowest to 22,6 °C at the highest point. The relative humidity was between 47% and 54%. The conditions met the requirements.

The readings in the gallery repository during March 2020 are shown in Figure 18.

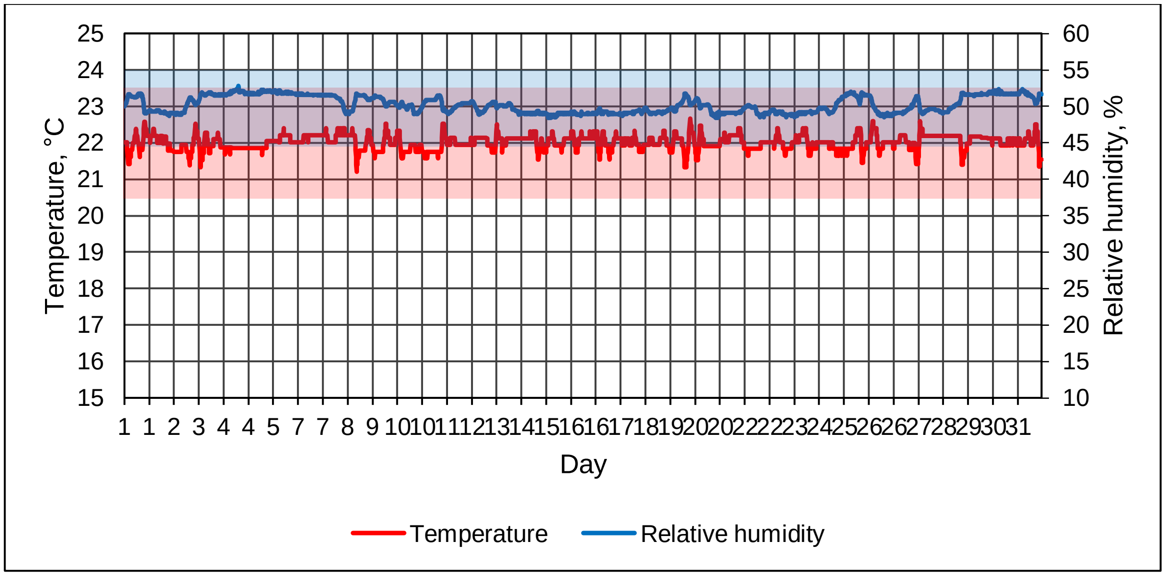

Figure 18. The temperature and relative humidity measurements in the gallery repository in March 2020

In March, the average values were 21,8 °C and 51% of relative humidity. The temperature was between 20,9 °C and 22,9 °C, the relative humidity – from 47% up to 53%. The values were within the limits.

During February and March 2020 the hygrothermal conditions in both the gallery and the gallery repository met the requirements. Based on the readings of these two months, the systems in the chosen premises seem to be working properly.

6 COMPARISON

The most obvious difference between the three evaluated buildings is the existence or lack of an automation system. In many types of buildings, building management systems (BMS) are convenient and useful for saving energy but often not necessary. In cultural institutions, where fragile items are stored or exhibited, BMS play a much more important role. In both the Palace of the Grand Dukes of Lithuania and Canberra Museum and Gallery, BMS record the temperature and relative humidity measurements. In the Cultural Heritage Centre, there is no such system. The readings of hygrothermal conditions in the archive are recorded by workers. It is only done every few days, sometimes only once or twice per two weeks. As a result, it is not possible to check if the conditions are proper during the night and if there are any severe fluctuations throughout the day.

BMS are not only useful for receiving and collecting accurate data. The state of the systems connected to most BMS can be checked remotely anytime. This is very helpful in case of accidents and emergencies. There are also possibilities to receive emails or other types of emergency messages and alarms when the connected systems experience issues. According to an engineer responsible for the HVAC systems in the Palace of the Grand Dukes of Lithuania, there were multiple such accidents. Once, a valve exploded because the pressure in the refrigeration system became too big. The refrigerant might have gotten heated by the sun and, as a result, expanded. An additional expansion tank was added to the refrigeration system so there would be no accidents like this again. Another time, the pipe connected to the steam humidifier got disconnected. The part of the wall next to it and the ceiling above it were damaged. They had to be repaired. If there was no BMS, these problems would only become apparent when the technical rooms were inspected or the conditions in the premises would change quite noticeably.

BMS are also very useful in large buildings. If the premises are small enough, it is possible to walk through them and check the conditions manually. However, if the building has multiple floors and many rooms, this will be very difficult to do. BMS allow for easy and accurate constant monitoring of the systems and conditions in the building.

The Palace of the Grand Dukes of Lithuania is also an example of the fact that a BMS and all its components should be installed correctly. As mentioned by the engineer working in the Palace, not all sensors pick up accurate temperature and relative humidity values. Some of them are hidden by furniture, installed too close to lighting equipment or experience connection problems. Consequently, the data gathered by the BMS cannot be fully trusted and it is not clear if the proper conditions are ensured or not.

7 DISCUSSION

The main aims of the thesis were to become familiar with the requirements of hygrothermal conditions in Lithuania and Australia as well as evaluate the measurements in the selected premises in three different buildings.

The Lithuanian requirements are more focused on specific values and ranges suitable for different materials. The Australian guidelines suggest broader ranges and provide more in-depth explanations of the processes that occur when certain indoor climate factors change. The presented values and limits in both countries cannot be compared because of the differences of climate and the natural acclimatisation of the materials and objects.

There were differences between the measurements of temperature and relative humidity in the three investigated buildings. During the selected months, the temperature in the Cultural Heritage Centre archive was within the limits. The relative humidity was significantly below the limit. The readings of two years showed not only that there are issues with relative humidity being too low most of the time, but that the heating and especially the cooling capacity seem to be too low as well. It is hard to make conclusions regarding the Palace of the Grand Dukes of Lithuania. It seems as if either the initial design values no longer apply to the current systems or the sensors are only able to measure very inaccurate values. Most of the time, the temperature of the chosen exhibition halls was above the design limit while the relative humidity did not reach the minimum limit. The fluctuations in the exhibition hall 4, regardless of the correct relative humidity values, are grounds for concern. The Canberra Museum and Gallery appears to be the only cultural institution out of the investigated buildings in which the proper hygrothermal conditions were maintained consistently.

As mentioned in the previous chapter, the Cultural Heritage Centre archive would benefit from having a BMS. Moreover, more data about the temperature and relative humidity should be gathered during the summer and winter. Based on it, the necessary cooling and heating capacities should be reconsidered. The supply of water to the humidifier should be investigated further as well. As for the Palace of the Grand Dukes of Lithuania, the setpoints of the hygrothermal conditions should be verified. In addition, the settings regarding the humidification should be checked.

The study suggests that more attention should be paid to the hygrothermal conditions in cultural institutions. Reoccurring deviations from the requirements should be noticed, possible reasons should be confirmed or disproved. As evident from this study, in order to make any conclusions, the analysed data should span at least an entire year. Further research could be done in areas with even hotter climates. Broader studies could be done by taking into account the building structure, e.g. cultural institutions in old historical buildings. Moreover, the hygrothermal conditions in display cases could be taken into account as well.

REFERENCES

1. Guidelines for Environmental Control in Cultural Institutions. Heritage Collections Council. 2002. Pdf document. Available at: https://aiccm.org.au/conservation/collection-care/. [Accessed 19.10.2020].
2. Instruction on Protection, Accounting, and Storage of Museum Collections. Ministry of Culture of the Republic of Lithuania. 2005. Word document. Available at: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.268789. [Accessed 13.7.2020].
3. Stefan Michalski. Agent of Deterioration: Incorrect Temperature. Government of Canada. WWW page. Available at: https://www.canada.ca/en/conservation-institute/services/agents-deterioration/temperature.html. [Accessed 16.10.2020].
4. Stefan Michalski. Agent of Deterioration: Incorrect Relative Humidity. Government of Canada. WWW page. Available at: https://www.canada.ca/en/conservation-institute/services/agents-deterioration/humidity.html. [Accessed 16.10.2020].
5. Stefan Michalski. Agent of Deterioration: Light, Ultraviolet and Infrared. Government of Canada. WWW page. Available at: https://www.canada.ca/en/conservation-institute/services/agents-deterioration/light.html. [Accessed 16.10.2020].
6. Jean Tétreault. Agent of Deterioration: Pollutants. Government of Canada. WWW page. Available at: https://www.canada.ca/en/conservation-institute/services/agents-deterioration/pollutants.html. [Accessed 16.10.2020].
7. Tom Strang, Rika Kigawa. Agent of Deterioration: Pests. Government of Canada. WWW page. Available at: https://www.canada.ca/en/conservation-institute/services/agents-deterioration/pests.html. [Accessed 16.10.2020].
8. HN 42:2009. Gyvenamųjų ir visuomeninių pastatų patalpų mikroklimatas. Ministry of Health of the Republic of Lithuania. Word document. Available at: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.362676. [Accessed 16.10.2020].
9. HN 69:2003. Šiluminis komfortas ir pakankama šiluminė aplinka darbo patalpose. Parametrų norminės vertės ir matavimo reikalavimai. Ministry of Health of the Republic of Lithuania. Word document. Available at: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.230880. [Accessed 16.10.2020].
10. Australian Institute for the Conservation of Cultural Material. Environmental Guidelines. WWW page. Available at: https://aiccm.org.au/conservation/environmental-guidelines/. [Accessed 19.10.2020].
11. Čiuprinskienė, J., Čiuprinskas, K., Motuzienė, V. Šildymas, vėdinimas, oro kondicionavimas. Vilnius: Super namai. 2019.
12. RSN 156-94. Statybinė klimatologija. Ministry of Construction and Urban Development of the Republic of Lithuania. 1995. Pdf document. Available at: https://remontogidas.lt/images/Kita/Statybine%20klimatologija%20RSN156-94.www.remontogidas.lt.pdf. [Accessed 19.10.2020].

13. Time and Date. Annual Weather Averages Near Canberra. WWW page. Available at: https://www.timeanddate.com/weather/australia/canberra/climate. [Accessed 28.11.2020].
14. Lithuanian Hydrometeorological Service. WWW page. Available at: http://www.meteo.lt/. [Accessed 28.11.2020].
15. Bureau of Meteorology. Australian Government. WWW page. Available at: http://www.bom.gov.au/. [Accessed 28.11.2020].
16. Jačauskas, I. Kultūros paveldo departamentui vadovauti siekia 7 asmenys. 15min. WWW page. Available at: https://www.15min.lt/naujiena/aktualu/lietuva/kulturos-paveldo-departamentui-vadovauti-siekia-7-asmenys-56-1051118. [Accessed 30.1.2021].
17. Cultural Heritage Centre. WWW page. Available at: http://kpc.lt/. [Accessed 20.7.2020].
18. National Museum Palace of the Grand Dukes of Lithuania. WWW page. Available at: https://www.valdovurumai.lt/. [Accessed 20.7.2020].
19. Costigan, P. Exhibition: Celebration 25 years of Collecting. The Art Museum. WWW page. Available at: http://www.theartmuseum.com.au/2018/05/08/canberra-art-gallery-25-yrs-collection/ [Accessed 30.1.2021].
20. Canberra Museum and Gallery, WWW page. Available at: http://www.cmag.com.au/. [Accessed 19.10.2020].
21. Canberra Museum and Gallery. Wikipedia. WWW page. Available at: https://en.wikipedia.org/wiki/Canberra_Museum_and_Gallery. [Accessed 19.10.2020].