STUDY ON MICROCLIMATE IN MUSEUM DISPLAY CASES

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In the world of art conservation, it is important that museum showcases are solid. The purpose of this research is to obtain an optimal width of the ventilation space around the base plate / display in the display case. The behavior of ProSorb adsorbents is also examined, as well as the parameters that influence conditioning. An optimal ventilation space (Fig. 1) is required to maintain relative humidity in the display to a constant level. When the museum showcase is subject to significant environmental fluctuations, this can have disastrous consequences for the art objects. Using simple electronic components, easy-to-use measuring equipment has been developed to collect data on relative humidity and temperature. The sensors were placed in different locations in a standard display case model.

Keywords: museum display cases, art conservation, microclimate

1. Introduction

Throughout the existence of humankind, art has always occupied a very important place in society. To protect a wide variety of artifacts against the effects of corrosion and wear, proper preservation is required. It is very important to achieve and maintain specific environmental conditions to prevent degeneration.

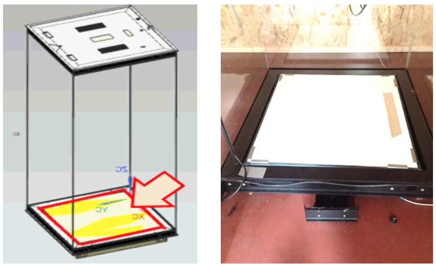

Fig. 1. Ventilation space in a museum showcase

In almost all museum display cases, an attempt is made to control the relative humidity of the air (hereinafter shown under the RH index) and to keep it

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constant within certain limits. It is the most important factor in the preservation of art objects.

To accomplish this, a buffer compartment with special material is provided inside the museums showcases. This material is usually placed under the motherboard / display window. An essentially free space of 10 to 20 mm is then provided around it to allow for good air circulation (indicated by the arrows in Fig.1) and the measurement procedures will be detailed in next chapters.

2. Passive climate control

The principle of passive climate control of showcases is entirely based on the ability of a material to adsorb or release moisture. In professional cases, silica gel is mainly used due to its low weight and high capacity. There are many other materials that can adsorb and remove moisture, such as wood, paper and textiles.

Buffering becomes more difficult when increasing the volume of the piece to be protected. Wood, paper and textiles can adsorb more moisture than air, which means that more silica gel will be needed to buffer an environment from a display case containing a large object.

3. Relative humidity

In the air we breathe, there is always a certain amount of water vapor. Relative humidity is expressed in percent and indicates the amount of water vapor in the air compared to the maximum amount of water vapor. This maximum quantity depends on the temperature. At 20 ° C, the maximum amount of water vapor will be, for example, 17 g / m³. When the actual amount of water vapor is 8.5 g / m3, RH is equal to 50%.

Fig. 2. Silicone pellets from the Silicagel box

Relative humidity is the central pivot in the science behind artefact conservation. Padfield [1], for example, stated that "a difference in absolute humidity means no difference in moisture absorption." The properties of an artifact object must remain the same under a constant RH. For example, with a low or high RH, the wood will shrink and expand, respectively. This is detrimental to the durability of the material.

In the past, silica gel was mainly used as an adsorbent (Fig. 2). Silica gel is composed of silicate moisture adsorbent solids crystals, made of sodium silicate (Na_2SiO_3). It has an internal network of interconnected microscopic pores.

This is very favorable for many reasons: high water adsorption capacity, chemical inertia because it does not react or react with other chemicals and the possibility of passing through an indeterminate number of humidity cycles. This method is very often described in the literature on the preservation of art objects [2], [3], [4].

4. Air Exchange Rate (AER)

One of the most important features of a museum showcase is tightness [5], [6], [7], [8], [9], [10].

Tightness is expressed as air exchange rate or AER. This value shows how quickly the air in the window case is replaced completely. For example, an AER of 1 means that after a day, the air in the display window was "restored". An AER of 0.1 means that it takes ten days to refresh the air. It goes without saying that an AER of 0.1 is more advantageous than a 1. This value meter does not only depend on the mechanical properties of the museum display case but also on external properties such as temperature.

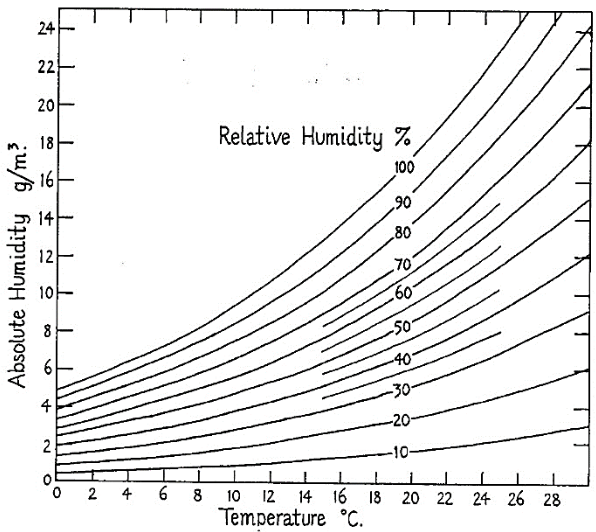

Fig. 3. Relative humidity chart [5].

For example, the temperature difference between indoor air and outside air should not be too high. "A temperature difference results in a difference in pressure, which in turn leads to an increase in the air flow between the showcase void and the external environment" [5].

5. Set up the test

We can have the best results with a good study and configuration of all the factors in the process. In order to make accurate measurements, everything must be as optimal and as close to reality as possible. It requires a space that we can condition, equipment to control the temperature in this environment and, consequently, to vary relative humidity and measuring equipment to measure relative humidity and temperature. This section provides a brief introduction to how the tests on the museum showcase to be improved have begun.

The museum display used in this test is a product of Meyvaert Glass Engineering (Fig.4). The standard model is a basic model, which can be extended with the help of several modules. It has an area of 1 x 1 m and is 2 m high. The lower part was also provided with a drawer that can be opened independently of the display cabinet. The intent is that ProSorb can be placed in it, while little or no air can enter the window. ProSorb emits or collects wet air through a network with a metal base plate. This base plate was designed in such a way that the free space intended for the air circulation is 10 mm. This space is required because it connects the air in the display window with the ProSorb active area (under the base plate).

Fig. 4. Typical museum showcase used in experiments

In order to simulate a museum environment as closest as possible and to isolate the environment we decided to build a wooden box around the showcase in Meyvaert's factory (Fig. 5). Even if the building has concrete walls, the available space for this test was a big room inside the production hall so the wooden structure will help to control easily the environment around the showcase and to proceed with our tests.

Despite the high insulating effect of the wood that we built around the showcase, large external influences on temperature were observed during the measurements.

Fig. 5. Wooden box built around the showcase

Although the thermostat in the building tried to keep the temperature constant, at certain moments there were temperature peaks. This was especially the case when the electric heating in the room where the display case was installed was on or off. Even at night, when the electric heating was turned off, the temperature dropped, this being visible in the measurements.

A solution to this problem could be isolation. By insulating the wooden box walls with insulation a few centimeters thick, the tip of these temperature fluctuations could be eliminated. For heating or cooling, an electric heater and an air conditioning unit are used. The air conditioning unit has a built-in thermostat, which can be used to set the temperature. Electrical heating is controlled with an external thermostat. Arduino sensors for temperature and humidity levels were installed at 50 cm height difference and the measurements were monitored for a period of two weeks helping the team to understand the interior environmental behavior.

Furthermore, in testing the most real results, were installed sensors in 12 showcases in the Shindagha-Historical District Museum in Dubai, United Arab Emirates (Fig. 6 and 7). It took advantage of the fact that the showcases were in the construction stage during pandemic in 2020, due to this fact sensors were installed in several of their positions, with and without the artifacts inside:

From the measurements performed with these Arduino humidity/temperature sensors it was concluded that in the small showcases under 2 meters high Prosorb worked perfectly and evenly buffered the entire interior volume of the showcase

Fig. 6. Custom museum showcases with the sensors and Prosorb placed inside the void

Fig. 7 – Humidity/temperature sensors placed under the base of the display case next to the Prosorb boxes and at the top. The interior height of the window is 2.6 meters.

In the showcases over two meters high after 3 days from the installation of Prosorb and the sealing of the showcase, it was observed that a linear buffer was obtained. After 3 days, the temperature at the top of the showcase increased, and the RH value rose by up to 20 percent difference from the base of the showcase after 2 weeks (Fig. 8).

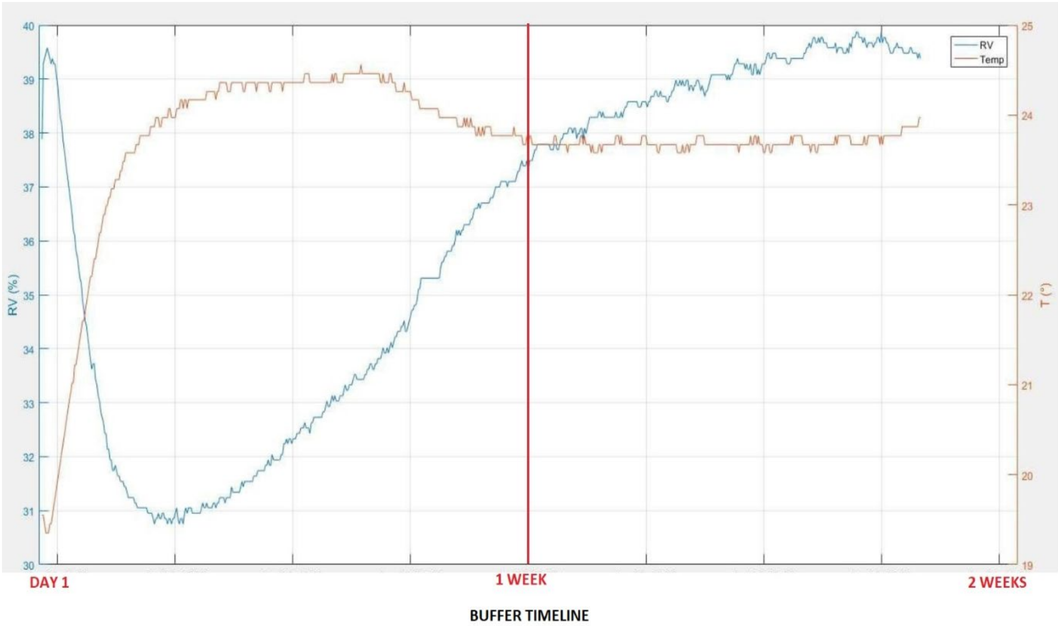

Fig. 8 – The value of the RH sensor at the top of a 2.6-meter high display showcase for a period of two weeks

7. The negative effects of poor maintenance and non-control of RH in the museum spaces

In the Qasr Al Watan Museum in Abu Dhabi, United Arab Emirates, during the isolation caused by the Covid-19 pandemic, the maintenance team turned off the air conditioning inside the building for a period of 5 months. The conservation team could no longer travel to the museum to monitor the artifact collection.

Fig. 9 - Mold stains on the inside of the Prosorb compartment in showcases exposed for a long time to an RH beyond the limits of preservation

During the museum's preparatory actions for reopening, mold stains were observed on the sides of the showcases, and the entire artifacts collection was removed from the showcases and restored under extremely high costs, because the humidity in Abu Dhabi is very high, given its location, desert area near a salty sea. Over a period of several months, the RH sensors recorded humidity between 70 and 75%.

8. Conclusions

In this first part of the research on the control of the microclimate inside the museum showcases, the stand and the test program were configured, in view of some calibration and optimization measurements.

In the **"ANNEXES"** part of the study will be presented the test program and the actual measurements. Following these measurements, the optimization elements will be established and constructive solutions will be proposed to improve the microclimate to protect the exposed artifacts.

Comparing the measurements, the distance between Prosorb, which is located at the base of the showcase and the top of it, is too big. As we have observed during testing, the air circulates inside the showcase. In this case, the top of the showcase was close to the ceiling of the room, and the difference in temperature and probably the high humidity in the environment led to a wrong buffer and to a big difference in values between the two areas. Prosorb buffers properly up to heights of 2 meters, but after this value, the above area is in danger of degradation.

To protect the artifacts from the effects of corrosion and degradation, proper preservation is required. It is very important to achieve and maintain specific environmental conditions to prevent the degradation of objects. In almost all museum showcases, it is tried to control the relative humidity of the air and to keep it constant within certain limits. It is the most important factor in preserving art objects.

As noted during the showcase multiple tests in the showcase from Meyvaert factory, a 10 mm to 20 mm vent space is then provide in the baseboard to allow good air circulation. Previous studies show that an RH level above 65% will fuel bacterial growth, while an RH level below 25% can lead to fragility and rupture. In addition, fluctuations in relative humidity can lead to dimensional changes, deformation and mechanical stress in organic materials. In the showcase with a height above of 2.6 meters, after a period of 8 weeks it observed that the difference in humidity relative from the top compared to the bottom was too high. The value at the top had the same value as the RH and temperature in the museum gallery - about 65%, which indicates that the artifacts were exposed to rapid degradation. The artifact in that showcase is a metallic material, and the value of RH recommended in terms of conservation is a maximum of 45% and a minimum of 40% for this material.

An attempt has been done to remedy this problem by reconditioning the silica gel and establishing a different value of relative humidity. This can be done by removing or adding moisture to the silica gel outside the display case or when it is still inside.

The most effective method of removing moisture is heating. Although silica gel has a very high melting temperature (1600 ° C), it already loses its hygroscopic properties at 300 ° C. In a conventional oven, the regeneration time varies from a few minutes to hours, depending on the temperature and the size of the granules. The easiest way to recondition the silica gel is to place it in a room with the desired level of relative humidity. Then check that the silica gel has reached the desired level. This is done by keeping a gel sample in a sealed container or in a closed bag together with a hygrometer. When it indicates the desired relative humidity, the reconditioning was successful.

In the case of the 2.6 meter showcase, it was reconditioned to the minimum recommended value for that material, respectively 40%. Usually Prosorb is placed inside the showcase at an average between the minimum and maximum value, respectively 42.5%.

Before measurements with ProSorb to start in the museum showcase, it must first be determined how quickly the showcase adapts to a change in temperature in the surrounding area. To determine this speed, open the first door of the showcase so that the temperature inside and outside is the same. Then the door have to be closed and the temperature inside the room to be raised to 25 ° C from 19 - 20 ° C as it was in our case during the testing. It is then concluded that the air inside the display case increased by 5 ° C after 3.5 hours.

The temperature in the showcase should remain constant under ideal circumstances to obtain accurate measurements. However, due to environmental influences, it is impossible for this temperature to be permanently constant at any time.

Even with Prosorb reconditioned to the minimum value, it can be seen that after 2 weeks from this process, the RH value at the top of the display case was the same as before - respectively 65%. At heights of more than 2 meters it is clear that the distance between Prosorb and the environment is too large and it no longer has the ability to absorb moisture at high altitudes. Attempts have also been made to introduce larger amounts of Prosorb into the display case, but the RH has decreased by only 2 percent from 65% to 63% while the maximum RH allowed is 45% for metal artifacts. On this case the conservators in charge of the artifacts collection should ask the showcases manufacturer to provide some fans below the baseboard.

The museum community acknowledges the practical difficulties, high cost and non-sustainability of maintaining flatlined relative humidity and temperature in the exhibition environment, and that a single standard is not suitable or necessary for all collection objects. Currently, the rational for maintaining the standard of 50 +/- 5% RH is based upon the assumption that drift will occur and that tight control is impossible to achieve. If standards are broadened, it will be crucial to ensure that the needs of individual objects, groups of objects, and sensitive materials are recognized and addressed by the use of microclimates or other mitigation measures. These changes may be at odds with curatorial, design, and aesthetic priorities, but may need to take precedence over them in order to ensure the long-term preservation of collections. Any alteration of standards will demand a greater understanding of case design and the use of microclimates to create appropriate environments for sensitive objects and a demonstration that the measure implemented are cost-effective. Developing alternate standards will require proper evaluation of the moisture content and sensitivities of objects in order to design safe and sustainable environments.

R E F E R E N C E S

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ANNEXES

Arduino programming - Defining variables and configuration feature

This section gives an image of the code with which we program the Arduino module. This is very important because it links the sensors to the PC we read the data. Arduino code is written in C++ with an addition of special methods and functions, which we will mention later on. C++ is a human-readable programming language. When you create a 'sketch' (the name given to Arduino code files), it is processed and compiled to machine language.

The first three lines take up some libraries that are required for the correct operation of the program (Fig.11). The "dht.h" library accepts only a function for sensing humidity and temperature reading. The SD library serves for reading and writing on an SD card. Finally, the "SPI" library allows the user to communicate with SPI devices, for example with the Arduino device as the primary device in this case.

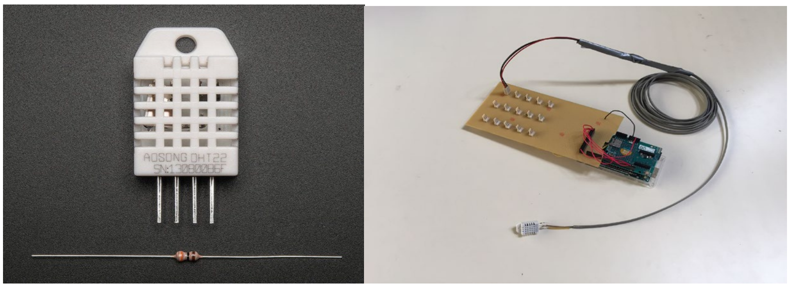

Fig. 10 Arduino programming/Arduino sensors

```
void setup()
{
  Serial.begin(9600);
  pinMode(pinCS, OUTPUT);
  if (SD.begin())
  {
    Serial.println("SD card is ready to use.");
  }
  else
  {
    Serial.println("SD card initialization failed");
    return;
  }
  Serial.println("Type,\tstatus,\tHumidity (%),\tTemperature (C)");
}
```

Fig. 11 Arduino programming

In later rules we define 15 variables, 1 for each sensor. With #define it is possible to give a name to a constant value before the program is put together. This constant value is actually the input pin on Arduino. The compiler will replace the references to these constants with the value determined during compilation. With the last line we will define a variable for the file we want to create to save the data.

The setup () function is called when a sketch begins. It is used to initialize variables and start running libraries. The configuration function can only be executed once, after each startup or reset of the arduino. SD.begin () initializes the SD card and returns a true / false value. Whether the SD card is ready for use or not, a corresponding message is displayed. Relative temperature and humidity are measured and displayed on the screen anyway.

After calling the setup () function, there is a loop function (). It is executed several times in succession and performs every function that is in this loop. Here it measures the relative temperature and humidity of each sensor, opens a text file called "TEST.txt", writes the data into this file and closes it.

```
#include <dht.h>
#include <SD.h>
#include <SPI.h>

dht DHT1, DHT4,DHT5, DHT6,DHT7,DHT8,DHT9, DHT10,DHT11,DHT12,DHT13,DHT14, DHT15;
dht DHT2;
dht DHT3;

#define DHT_PIN1 23
#define DHT_PIN2 25
#define DHT_PIN3 27
#define DHT_PIN4 29
#define DHT_PIN5 31
#define DHT_PIN6 33
#define DHT_PIN7 35
#define DHT_PIN8 39
#define DHT_PIN9 41
#define DHT_PIN10 43
#define DHT_PIN11 30
#define DHT_PIN12 28
#define DHT_PIN13 26
#define DHT_PIN14 24
#define DHT_PIN15 22


File myFile;
int pinCS = 53; // Pin 10 on Arduino Uno
```

Fig. 12 Arduino setup function programming.

With a delay () the program is interrupted for the time period, in milliseconds, specified as a parameter. The parameter given here is very important. This determines the time interval between two successive measurements

The read_sensor1 (int pin, DHT) function (Fig.4) performs a measurement for the sensor whose input pin is given as a parameter. This is the name of the variable that was declared at the beginning. The program reads "DHT" connected to the "pin" and fills the relative temperature and humidity. The read () function checks the data transfer control amount and has a timing function

```
void loop()
{
  lees_sensor1(DHT_PIN1, DHT1);
  lees_sensor2(DHT_PIN2, DHT2);
  lees_sensor3(DHT_PIN3, DHT3);
  lees_sensor4(DHT_PIN4, DHT4);
  lees_sensor5(DHT_PIN5, DHT5);
  lees_sensor6(DHT_PIN6, DHT6);
  lees_sensor7(DHT_PIN7, DHT7);
  lees_sensor8(DHT_PIN8, DHT8);
  lees_sensor9(DHT_PIN9, DHT9);
  lees_sensor10(DHT_PIN10, DHT10);
  lees_sensor11(DHT_PIN11, DHT11);
  lees_sensor12(DHT_PIN12, DHT12);
  lees_sensor13(DHT_PIN13, DHT13);
  lees_sensor14(DHT_PIN14, DHT14);
  lees_sensor15(DHT_PIN15, DHT15);


  myFile = SD.open("TEST.txt", FILE_WRITE);
  myFile.println();
  myFile.close();
  Serial.println();


  delay(10000);
}
```

Fig. 13 Arduino Loop function ()

With a control error, the temperature and / or humidity values may still be correct. The read () function returns the following value:

- DHTLIB_OK (0): If the sensor sample and its control amount are OK.
- DHTLIB_ERROR_CHECKSUM (-1): if the check summary test failed. This means that data is received but possibly incorrect.

- DHTLIB_ERROR_TIMEOUT (-2): if an expiration time has occurred or communication has failed.

With a DHTLIB_ERROR_TIMEOUT relative humidity and temperature, both values will be

- DHTLIB_INVALID_VALUE. At DHTLIB_ERROR_CHECKSUM, humidity and temperature values remain unchanged.

In this function, there are commands for displaying and writing relative temperature and humidity.

```
void lees_sensor1(int pin, dht DHT){
  Serial.print("DHT, \t");
  int chk = DHT.read22(pin);
  switch (chk)
  {
  case DHTLIB_OK:
    Serial.print("OK,\t");
    break;
  case DHTLIB_ERROR_CHECKSUM:
    Serial.print("Checksum error,\t");
    break;
  case DHTLIB_ERROR_TIMEOUT:
    Serial.print("Time out error,\t");
    break;
  default:
    Serial.print("Unknown error,\t");
    break;
  }
  // DISPLAY DATA
  Serial.print(DHT.humidity*0.952161, 1);
  Serial.print(",\t");
  Serial.print(DHT.temperature*1.024635, 1);
  Serial.print("\t");

  //SAVE DATA

  schrijf_data1(DHT.humidity*0.952161, DHT.temperature*1.024635);

}
```

Fig. 14 Read_sensor Function ()

The write_data1 function (double humidity, double temperature) opens the created text file. If this does not happen, the value has been added to the bookstore. When this is correct, we write in the compiler exactly as described in this function.