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MICROCLIMATE CONTROL IN MUSEUM DISPLAY CASES

Abstract: *Museum showcases are systems that ensure the protection of artifacts, sometimes of inestimable value. When the museum showcase is subject to significant environmental fluctuations, it can have disastrous consequences for works of art. Using simple electronic components, easy-to-use measuring equipment was developed to collect data on relative humidity and temperature.*

Key words: *museum display cases, art conservation, microclimate.*

1. INTRODUCTION

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. 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 constant within certain limits.

To accomplish this, a buffer compartment with special material is provided. 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 Figure 1).

Figure 1 Museum display case [6].

Some studies [1] realized by "British Museum - Department of Conservation and Scientific Research" have shown that a Relative Humidity (RH) of more than 65% will promote bacterial growth, while a RH below 25% may lead to fragility and breakage. In addition, relative humidity fluctuations can result in dimensional changes, deformation and mechanical stress in organic materials. Today it is possible to acquire a mechanical dehumidification system - miniclimate systems, but this is often not done because of the high-cost factor and the difficulty of integrating them into existing structures. Taking into account the aesthetic aspect, these systems are also not favorable because they occupy a fairly large space, which is not recommended in this area and requires a rather careful maintenance. An alternative method that is often used is the use of an adsorbent material but used in a very well-sealed environment - in our case the museum showcase, aiming to create a micro-environment inside it. For this purpose, it is attempted to reduce the large fluctuations of RH that occur in general.

2. PARAMETERS THAT INFLUENCE THE ADSORPTION EFFECT

There are many parameters that influence the adsorption effect of the environment used and will be further analyzed. Issues related to this process and to be investigated are:
- the relationship between free space and performance; is there an effect on buffering speed?
- effect of the usual ambient air on performance; is there a linear relationship between ambient air and buffering speed?
- influence of the air volume; is there a maximum volume of air that can be conditioned?
- the difference in performance between free space around the motherboard and / or a perforated base spot;
- the effect of adding some fans; possibility to add timed fans; axial and tangential fans.

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. METHODS FOR CONTROLLING RELATIVE HUMIDITY

Absolute humidity is the measure of water vapor (moisture) in the air, regardless of temperature. It is expressed as grams of moisture per cubic meter of air (g/m^3).

The maximum absolute humidity of warm air at 30°C is approximately 30g of water vapor – 30g/m^3. The maximum absolute humidity of cold air at 0°C is approximately 5g of water vapor – 5g/m^3.

Relative humidity also measures water vapor but relative to the temperature of the air, being expressed as the amount of water vapor in the air as a percentage of the total amount that could be held at its current temperature.

Warm air can hold far more moisture than cold air meaning that the relative humidity of cold air would be far higher than warm air if their absolute humidity levels were equal.

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/m^3. When the actual amount of water vapor is 8.5 g/m^3, RH is equal to 50%. Relative humidity is the central pivot in the science behind artefact conservation. Padfield [24], 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.

3.1. Using silica gel for preservation of art objects

In the past, silica gel was mainly used as an adsorbent. 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.

Figure 2 Silica gel pellets.

The principle of operation of silica gel is based on adsorption and desorption of water molecules. Weintraub [2], a pioneer in the field of air conditioning and art conservation, describes it with the following words: "Silica gel is a chemical inert, non-toxic, or amorphous silicon dioxide, has an internal network or interconnected microscopic pores with a typical surface area of 700-800 square meters per gram or, in other words, the inner surface area of a teaspoon filled with silica gel is equivalent to a football field. Water molecules are adsorbed or desorbed by these microcapillaries until the vapor pressure equilibrium is reached with the relative humidity of the surrounding air."

Silica gel (Figure 2) is an amorphous and porous form of silicon dioxide (silica), consisting of an irregular tridimensional framework of alternating silicon and oxygen atoms with nanometer-scale voids and pores.

To understand how the silica gel works, it is important to understand the concept of "Moisture Humidity Balance" or MHB. Many materials contain moisture. The moisture content of the hygroscopic materials depends on the temperature and relative humidity of the surrounding air. There is a balance. When one of the parameters changes, the moisture content of the object will be adjusted to create a balance with ambient air. This equilibrium condition is thus achieved after buffering.

The moisture content of an object is the weight of the water in an object, expressed as a percentage of its dry weight. There will be an MHB condition if the water vapor is no longer absorbed or rejected. Then, the moisture content of an object is in balance with a certain relative humidity. This status can also be displayed in quantitative terms.

Following the MHB concept, it fits the idea of hygrometric half-life developed by Thomson [3]. Many processes in nature operate in accordance with a simple rule, namely that of exponential decay. For example, if we have a relative humidity of 90% at an ambient temperature of 25%, MHB will try to achieve a balance. The intermediate value is 62.5%. The time to reach this value is measured and is called the half-life. Suppose this takes 2 hours in this case. When the time is now measured to go from 62.5% to ½ x (62.5 + 25) = 43.75%, it is again 2 hours. The time from 43.75% to ½ x (43.75 + 25) = 34.4% is again 2 hours and so on. The half-life will always be 2 hours in this example.

Hygrometric half-life is therefore the time required to achieve an RH value. This value is the between the RH value of the silica gel and the RH value in the case of the museum showcase.

Thomson introduced the concept of hygrometric half-life (Figure 3), which while a simplification of reality has provided beneficial insights for many years. t1/2 =4MB where t ½ is the hygrometric half-life (days) is the loading of absorbent in the chamber (kg/m^3).

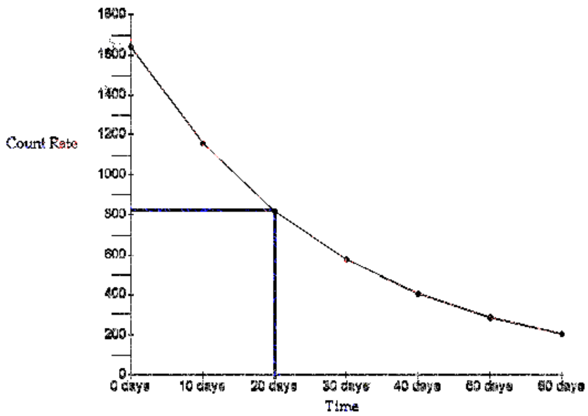

Figure 3 Thompson Crizzling Case experiment [3].

This is expressed by the following formula:

$$t_{\frac{1}{2}} = \frac{4760 \, x \, M \, x \, B}{N} \quad (1)$$

In formula (1), M is a first important factor, the mass of water in grams that is absorbed or released per kilogram of buffer (silica gel) at a change of 1% RH. Therefore, a high M value is a necessity to achieve acceptable relative humidity. Increasing the M value ensures faster adsorption and therefore we need less adsorbent material. According to Thomson [3], however, the hygrometric half-life essentially depends on two factors: the air exchange rate N and the amount of buffer material B in the museum show case. B is the dry mass of the buffer in kg/m³. By lowering the Air Exchange Rate (AER) or increasing the amount of buffer material, the hygrometric half-life will increase.

By lowering the AER or increasing the amount of buffer material, the hygrometric half-life will increase and we can better control the RH level. How long will it maintain? What amount is recommended? These are common questions about the silica gel. The recommendations for the amount of silica gel range from 2 kg/m³ for RD6 silica gel to 0.5-1 kg/m³ for Art-Sorb.

The difference between these values is not so much due to the buffering capacity, but in particular to the formulas used to determine these quantities. When estimating the amount of silica gel required to buffer or to achieve relative humidity, different conditions have to be taken into account.

It is possible to refill the silica gel and establish a different value of relative humidity. This can be done by removing or adding moisture to the silica gel, outside / inside the window case. The most effective method of removing moisture is heating. Although the silica gel has a very high melting temperature (1600 °C), it loses its hygroscopic properties already at 300 °C. In a conventional furnace, the regeneration time varies from a few minutes to hours depending on the temperature and thickness of the gel layer.

The easiest way to condition the silica gel is to place it in a room with the desired level of relative humidity. Then check whether the silica gel has reached the desired level. This is done by stopping a gel sample in a sealed container or in a closed bag together with a hygrometer. When indicating the relative humidity, the refurbishment was successful.

3.2 Tightness

One of the most important features of a museum showcase is tightness. The better it is sealed, the better the buffer will be. In case of low tightness, a large part of the air will infiltrate from the outside into the window housing. The outside air will have an RH value different from the air inside the display case, which means that ProSorb needs to tampon more. All this leads to an increased uncertainty of relative humidity and increased cost of the buffer material.

Tightness is expressed as air exchange rate or AER. AER is measured by the addition of CO_2 gas. The gas is first injected into the sealed window case. Sensors inside the vitrine will measure the concentration of CO_2 gas. In this way, it can be determined how long the air in the display window has to be refreshed

Thickett [4] investigated the effect of tightness on buffering and relative humidity control. By establishing the various tests, he tried to reach a clear conclusion with the help of sound measuring equipment. If the buffer content could be accurately measured, i.e. in showcases containing few hygroscopic materials and large quantities of silica gel, the hygrometric half-life was calculated using the Thomson formula, determined in one of his experiments [3]. Thomson's model predicts that a plot of ln (C-R) versus time (t) should yield a straight line. (C is the RH within the case at time t and R is the average RH of the surrounding air).

Models were also simulated based on the Tetrault & Weintraub formula (2), in which isothermal conditions are not required. Weintraub and Tetrault [5] developed an equation to determine the amount of silica gel required to buffer to a given RH fluctuation, which can be modified to estimate the time taken to reach a given RH.

$$t_{RH} = \frac{M_H \, F \, B}{C_{eq} \, D \, N} \quad (2)$$

where: t_{RH} is the time to reach a specified RH (days);

F is the targeted range of RH fluctuation (%);

M_H is the specific moisture reservoir corrected for hysteresis (no units);

B is the loading of absorbent in chamber (kg/m^3);

C_{eq} is the equilibrium concentration of water vapors (g/m^3);

D is the decimal difference between external RH and chamber (no units).

4. SHOWCASE APPLICATIONS

For showcases where the buffer content cannot be accurately measured, for example in wooden constructions, the patterns are made by changing the hygrometric half-life.

A first test was conducted with archaeological iron to a showcase in the foyer of the English Heritage head office. This is one of the least stable materials and can very quickly deteriorate to RH levels of over 16%. In order to keep this material, polypropylene silica gel boxes are often used. Over two years, four models and more than 30 boxes were tested. Both the Thomson model and the Tetrault & Weintraub model have delivered good results. A museum display was then projected with an AER of 0.4 to expose fragile archaeological metals to a damp environment. Again, very good results were obtained with Thomson and Tetrault & Weintraub. RH of 20% was maintained for 12 months. We expected Thomson's model not to be fulfilled because the temperature between the display case and the environment is not the same.

In another test, a lead box and skeleton were kept in a damp building. The relative humidity fluctuated between 25 and 65%, and in the case of the vitrine, the silica gel was replaced with dry gel after six months. By lowering the AER and replacing the silica gel with ProSorb, it was possible to control RH better between 50 and 65%. Low and dangerous RH levels have been avoided.

In another situation it became clear that RH was very low in winter and spring. As the performance of these showcases did not meet the requirements, they were again sealed by other methods as best as possible. AER has been reduced from 4, 5 and 6 per day to 0.6 to 0.8 per day. In this way it was possible to maintain a RH level of over 40%.

As expected, the importance of the air exchange rate with the outside was confirmed. Thickett [4] concluded that it is much easier to check the relative humidity when the AER is very low. He also was able to verify whether these comparisons developed by Thomson, Tetrault & Weintraub have a considerable potential to predict the internal climate in the museum's showcases. There are limitations with these formulas. For example, this approach will give false results in the case of large differences in indoor and outdoor temperatures, for example due to accidental illumination of the sunlight on the display.

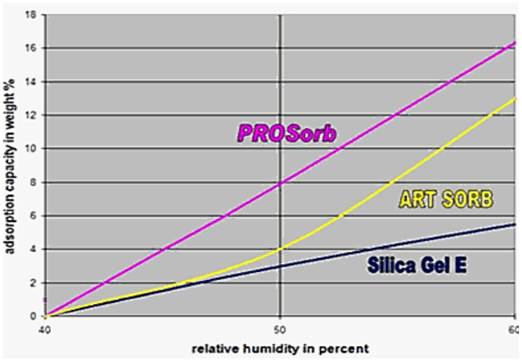

Figure 4 Adsorption capacity in the humidity range 40-60%.

In addition to common silica, there are other adsorbents such as ArtSorb and ProSorb. The environment with which we will work is that of ProSorb material. This is a silica gel with a small amount of alumina (Al2O3) that makes it possible to have a relative humidity of 40 to 60% that can be achieved by favorable adsorption capacity with an ideal RH level for museum displays case. ProSorb has a linear adsorption coefficient. This means that linear growth of RH content is always a constant amount of moisture to be absorbed (Figure 4).

The amount of ProSorb needed to reach a certain relative humidity depends on several factors. This amount of ProSorb is crucial to the accuracy of adsorption. With each buffering, ProSorb absorbs moisture or gives moisture to the cassette where it is seated.

5. CALCULATION OF SAMPLES

In a display case with a temperature of 20 ° C and a relative humidity of 60%, add 1 kg of ProSorb, which has been conditioned to 50%. From the water vapor properties (see Fig.2) we know that there is an absolute amount of water vapor of 10.8 g / m³ in air at 20 ° C and 60% RH. To reach 50% RH, however, only 9 g / m3 of water vapor may be present. At the showcase with a volume of 2 m³, 2 x 1.8 g = 3.6 g of moisture will be absorbed by ProSorb.

The percentage of moisture in a gel box is compared to its dry weight. This is the weight if the box is conditioned at 0% RH. This is why we know that this 1 kg ProSorb box is conditioned at 50% RH if there are 304 grams (30.4% x 1 kg) of moisture. ProSorb now has 307.6 g (304 g + 3.6 g) of water vapor.

ProSorb and the internal volume of the vitrine reach a balance when both relative humidities are equal. It can be deduced by interpolation that the ProSorb RH itself increased to 50.46%. It can be said that a steady state is reached in the window to 50.46% RH. If the number of cassettes increases, this MHB condition will decrease.

Nowadays, a rough estimate is made with all the parameters considered. Subsequently, the relative humidity level is accurately monitored with a hygrometer. When the desired level is not reached, the amount of buffer may be increased or decreased.

4. CONCLUSIONS

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.

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 second part of the paper will be presented the test program and the actual measurements.

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