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TEST OF A DEVICE FOR THE ACTIVE CONTROL OF ENVIRONMENTAL HUMIDITY IN MUSEUM DISPLAY CASES

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Abstract

A series of laboratory tests were conducted on a commercial device for active relative humidity control of display cases to assess the ability of the machine to control a medium format (3.45 m3) museum display case. An extreme museum environment with large relative humidity and temperature fluctuations was simulated and different air leakage rates were produced (0.1 - 0.5 - 6 AER/day) on a purposely-made display case. The machine was shown to work very effectively for both in humidify and dehumidifying for conditions corresponding to very well sealed (AER 0.1) to medium sealed (AER 0.5). On a very poorly sealed enclosure (AER 6), the external environmental fluctuation resulted in internal fluctuations but the machine very effectively mitigated these effects. The use of the machine in positive pressure mode and (optional) recirculating mode was shown to be irrelevant to the ability of the machine to control the relative humidity. Positive pressure mode provides a constant flow to remove VOC's from the showcase (which could contribute to artefact degradation.), and to prevent ingress of ambient pollutants.

Keywords: *Museum; Showcase; Climate; Active conditioning; Microclimate; Relative humidity*

Introduction

Appropriate climate control within museums and heritage buildings is still a major unsolved problem in heritage conservation. This is well documented in a large number of papers. Two reports making the point on the matter have recently been published by [1] and [2]. Unfavourable environmental conditions inside buildings and museums have important consequences on the well-being of visitors and workers and climatic fluctuations have serious impact on structures and collections. The subject is so important that the ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers - has released a specific handbook on the subject [3] where performance targets are given as well as the expected performance of various specifications options. On this subject, within the 7th Framework Program of the European research, a project named Climate for Culture (2009-2014 Grant Agreement no. 226973) was financed to analyse the effects of climate change on historical buildings and developed strategies for long-term preservation [4]. The main environmental parameters influencing the collections conservations were identified by [5] as to be: relative humidity, atmospheric pollution, noise and vibration, temperature, illumination. a) Relative humidity fluctuations produce changes in size and shape of the exhibits with associated stresses, change in the rate of deterioration because of chemical reactions, changes in biological deterioration sources. b) Atmospheric pollution can produce particulate deposition as well as

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chemical degradation. c) Noise and vibrations can cause mechanical damages as well as the inconvenience of visitors. d) Temperature can result in accelerated chemical degradation or accelerated water adsorption/desorption. e) Illumination can accelerate chemical degradation, discolour, increase the temperature. The control of these parameters at building level is very complicate, energy demanding and expensive. A local approach to stabilize the immediate encased environment of the object to be conserved has been adopted by the development of display cases. On this specific field guidelines for the design of showcases for cultural heritage preservation were published as European standard EN 15999-1 in 2014 [6]. A new standard defining the characteristics and conditions for use of showcases is actually under definition as prEN 15999-2 [7]. Also the procedures and the instruments to measure the relative humidity as well as the moisture exchanges between air and cultural property were defined in the European standard EN 16242 published in 2012 [8]. Display cases, if well made, give to cultural property a good protection against atmospheric pollution and relative humidity as well documented in [9-13]. In particular the protection against relative humidity fluctuations can be obtained both with passive and active systems and the evolution of these systems is well described in [14].

Different solutions for active relative humidity conditioning can be found today on the market working with different principles. Preservatech's Mini One is a device conceived to control the relative humidity of display cases from 35% to 80% for up to 10m^3 of volume. The machine operates by controlling the temperature of a water tank in contact with the air circulation system in order to attain the vapour pressure desired to get the correct relative humidity. The device can work in two modes: positive pressure mode and recirculating mode. In positive pressure mode intake air from outside the display case is pumped through the Mini One for conditioning and then injected into the display case at very low pressure. The result is a positive pressure inside the display case and a continuous air flow out through the leaks in the display case. In this configuration, the device is connected to the display case with only one pipe, and a single unit can be used to control relative humidity in multiple showcases. The interest of positive pressure mode is the prevention of the entrance of dust and other external pollutants and at the same time the expulsion of undesired Volatile Organic Compounds (VOC) that could produce further damage [15].

In recirculating mode the air is recirculated from inside the display case and reinjected after conditioning. In recirculating mode two pipes are needed (one input and one output) and neutral pressure is achieved inside the display case.

The device needs to be powered for 24h. In case of power supply gap the unit will restart operating automatically to the same target set before the gap. Several tests were conducted on a medium volume showcase in order to analyse the ability of the device to control the relative humidity of a big display case under simulated extreme environmental conditions.

Material and methods

The test was conducted as a simulation of a museum environment with extreme fluctuations of temperature (T) and relative humidity (RH). The room temperature was varied between the extremes of 12 and 24°C and the RH between the extremes of 30 and 90%. A medium volume display case 2.3m long, 1.5m deep and 1.0m tall was built for a total volume of 3.45m^3. This volume was chosen on the base of the most frequently requested to the device producer. For higher volumes a lower promptness of the device to control relative humidity should be expected while for lower volumes a higher promptness should be expected. The display case was made with gas barrier plastic film suspended to a wooden frame perfectly sealed in the junctions. Any kind of hygroscopic material was present inside the built display case. The pipes length was: 0.9 m from pump to Mini One and 2.0m from Mini One to display case for positive pressure configuration (see Fig. 1). In recirculating mode a pipe of 2.6m was added to connect the display case output to the pump input (the output was placed on the

opposite side of the input in order to allow an optimal air flow – see Fig. 1). The Mini One regulation sensor was placed 10 cm from the display case conditioned air input.

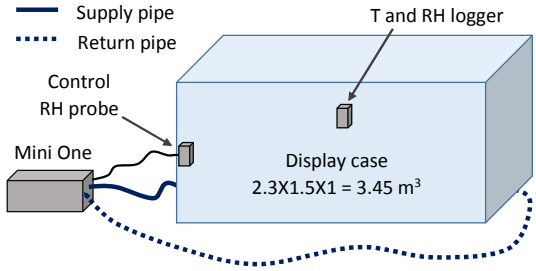


Fig. 1. Mini One and display case connections

Three different tightness configurations were tested in order to simulate different display cases: very good tightness, conventional tightness and very poor tightness. The different tightnesses were achieved by producing holes of different dimensions to the perfectly sealed box. The tightness was measured with the CO_2 method proposed [16]. The tightness is expressed in AER (Air Exchange Rate) per day, meaning that the number of times the air gets completely changed inside the display case during a day. The tightness was determined with the Mini One switched off because is to be considered as a property of the display case that would be altered by the air pump pressure. The three conditions tested were:

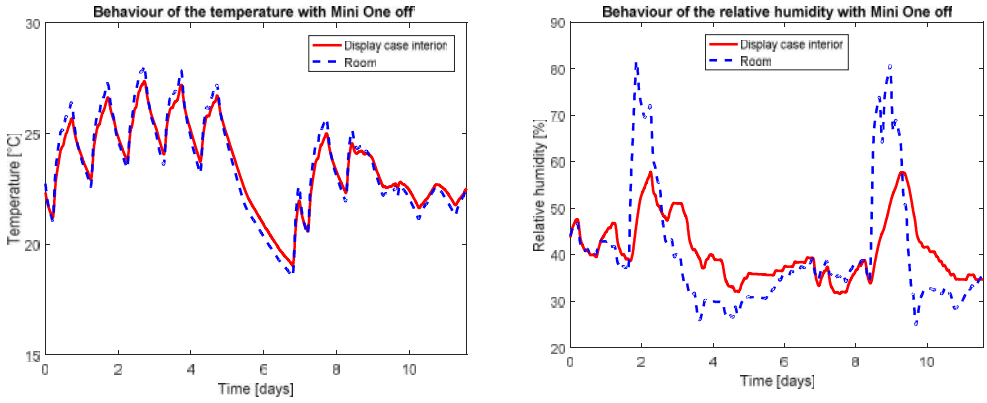
- Very good tightness – AER/day 0.1 – produced with two holes of 14mm of diameter;
- Conventional tightness – AER/day 0.5 – same holes as for AER 0.1 plus a rectangular hole of 106 mm by 80mm;
- Very poor tightness – AER/day 6.1 – same holes as for AER 0.5 plus a rectangular hole of 100mm by 200mm.

The Mini One operation was tested at low (45%) and high (65%) relative humidity targets for very good tightness and conventional tightness conditions. The very bad tightness condition was tested at intermediate (55%) relative humidity target both in positive pressure and recirculating configurations.

Independent data loggers produced by CEAM Control Equipment model C310 were used to acquire the display case internal and external (room) RH and T during the experiments. The accuracy of the sensors was ±3% for RH and ±0.3°C for T. The sensor logging the display case internal RH and T was placed in the centre of the display case while the sensor logging the exterior of the display case (RH and T of the room) was suspended in the proximity of the display case.

Case characterization

A reference test was conducted with Mini One off in order to check the effect of the room environmental fluctuations on the display case internal microclimate with an AER of 0.5. T was a wintertime daily heating simulation with a large variation between day and night. The internal T has shown to follow perfectly the external one highlighting a negligible influence of the case (see Fig. 2a). For RH external fluctuations going from +40 to -15% from the median of the whole period (see Fig. 2b), the display case interior gradually followed the room variations according to the time necessary to the diffusion to take place. These external fluctuations produced large display case internal variations going from +20 to -10% from the median of the whole period. This test is supposed to be a reference for comparison with the tests performed with Mini One switched on.



a **b**

Fig. 2. Behaviour of the temperature (a) and of the relative humidity (b) inside and outside the display case with Mini One switched off

Effect of Mini One on the display case internal temperature

In Fig. 3 are shown the display case and the room temperature with Mini One operating. The test was done with AER 0.5 and with an RH target of 45%. As can be observed the effect of Mini One on the temperature is negligible at conventional temperatures and becomes visible only at low temperature such as 12°C. This temperature cycle is typical of the other tests performed on the device and will not be shown for the following tests.

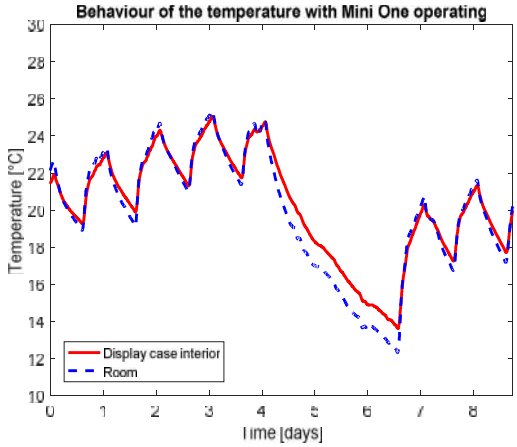


Fig. 3. Room and display case temperature with Mini One operating at AER 0.5 and 45% RH target. The influence of Mini One on the internal temperature is negligible

Results

Mini One operating in positive pressure mode with AER 0.1

Target 45% RH

The display case relative humidity was largely kept inside the ±5% RH from the target with external fluctuations going from +40% to –20% RH (see Fig. 4). Similar conditions with Mini One off resulted in an internal overall fluctuations of 30% RH.

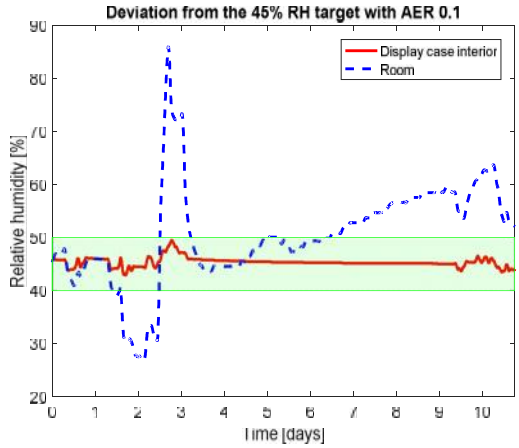


Fig. 4. Deviation of the display case relative humidity from the 45% RH target in a fluctuating external environment. Mini One operating in positive pressure mode with an AER of 0.1. The variation inside the green box are within ±5% RH from the target.

Target 65% RH

The display case relative humidity was largely kept inside the ±5% RH from the target with external fluctuations going from +30% to –25% RH (see Fig. 5). Similar conditions with Mini One off resulted in an internal overall fluctuations of 30% RH.

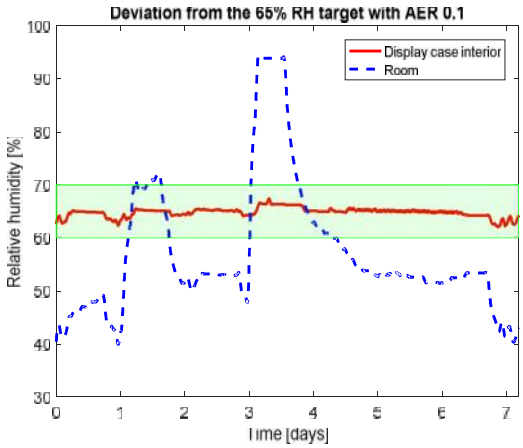


Fig. 5. Deviation of the display case relative humidity from the 65% RH target in a fluctuating external environment. Mini One operating in positive pressure mode with an AER of 0.1. The variation inside the green box are within ±5% RH from the target

Mini One operating in positive pressure mode with AER 0.5

Target 45% RH

The display case relative humidity was largely kept inside the ±5% RH from the target with external fluctuations going from +25% to –20% RH (see Fig. 6). Similar conditions with Mini One off resulted in an internal overall fluctuations of 30% RH.

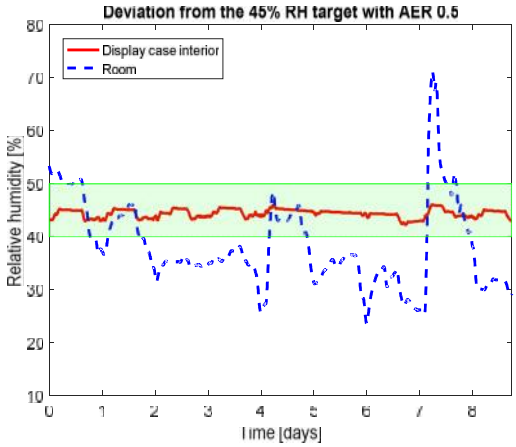


Fig. 6. Deviation of the display case relative humidity from the 45% RH target in a fluctuating external environment. Mini One operating in positive pressure mode with an AER of 0.5. The variation inside the green box are within ±5% RH from the target

Target 65% RH

The display case relative humidity was largely kept inside the ±5% RH from the target with external fluctuations going from +25% to –35% RH (see Fig. 7). Similar conditions with Mini One off resulted in an internal overall fluctuations of 30% RH.

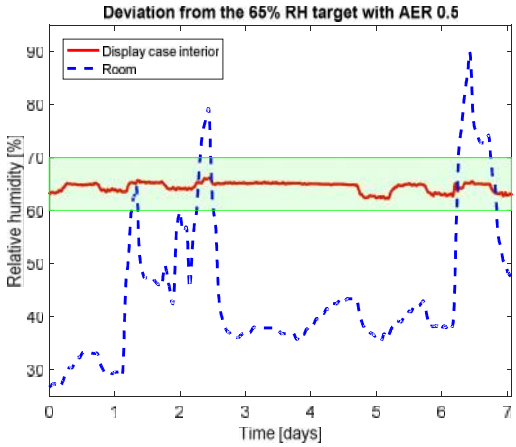


Fig. 7. Deviation of the display case relative humidity from the 65% RH target in a fluctuating external environment. Mini One operating in positive pressure mode with an AER of 0.5. The variation inside the green box are within ±5% RH from the target

Test with MiniOne operating in positive pressure and recirculating mode with AER 6 and an RH target of 55%

Mini One has shown to produce large attenuation of the RH variations at AER 6 both in positive pressure than recirculating mode (see Fig. 8). The display case RH with AER 6 and Mini One operating is more stable than with Mini One switched off and AER 0.5 as reported in Fig. 2. In particular is to be noted a very good attitude to hold RH very close to target value even with much lower external humidity. It should be also noted that an RH spike of +50% in a few hours is a very extreme case adopted in order to verify the difference between positive pressure mode and recirculating modes. As can be observed not relevant differences can be reported between the two working principles.

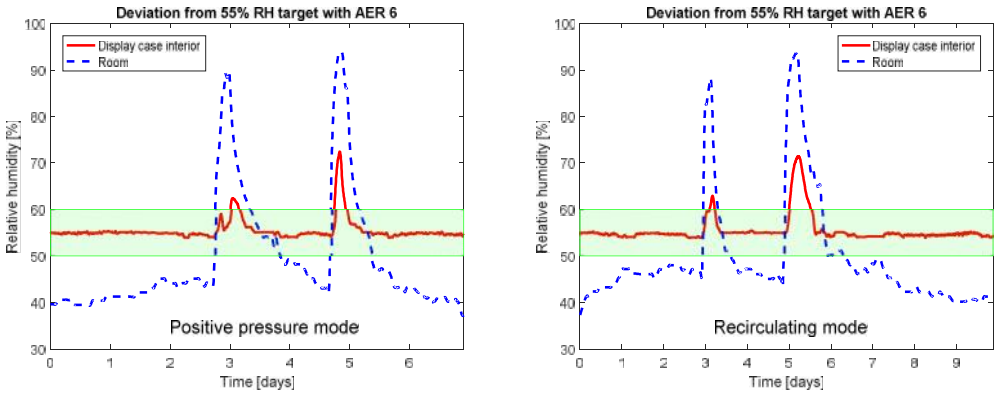


Fig. 8. Deviation of the display case relative humidity from the 55% RH target in a fluctuating external environment. Mini One operating in positive pressure mode (a) and in recirculating mode (b) with an AER of 6. The variation inside the green box are within ±5 % RH from the target

In order to have a better highlight of the efficiency of positive pressure and recirculating modes the time necessary to perform a humidity step was recorded with a very critical condition as with AER 6. The principle is that the more effective method would result in a more rapid step completion. A +20 RH step (going from 45 to 65%) and a -20 RH step (going from 65% to 45%) were executed with positive pressure and recirculating configurations and the results are reported in Table 1. As can be observed, the difference between the two configurations is very small and they can be considered equivalent. The machine clearly shows a better ability to humidify than to dehumidify.

Table 1. Time necessary to Mini One to complete a humidifying step going from 45 to 65% RH and a dehumidifying step going from 65 to 45% RH in positive pressure mode and recirculating mode

Operation	Step	Mode	Time [h:mm]
45 to 65% RH	↑	Positive pressure	2:24
65 to 45% RH	↓	Positive pressure	3:20
45 to 65% RH	↑	Recirculating	2:53
65 to 45% RH	↓	Recirculating	3:20

Conclusions

Mini One unit has shown to behave very effectively for the relative humidity control of a large display case of 3.45 m^3. The device has shown to not affect the temperature of the showcase. With AER 0.1, corresponding to a state of the art display case tightness, the machine has performed very well both at low humidity (45%) than high humidity (65%) targets. The display case interior was largely kept within 5% from the targets with very severe room conditions. The same is to be said for an AER of 0.5 corresponding to a conventional tightness. The unit has shown to give a strong support to reduce relative humidity spikes even with very poor tightness conditions such as AER 6 (corresponding to big holes on the display case). Positive pressure mode and recirculating mode have not shown relevant differences for conditioning capacity or accuracy. Working with relative humidity steps has shown a very similar behaviour for both positive pressure and recirculating modes. A better ability of the unit to humidify than to dehumidify was also recorded, which is in line with the specifications sheet. The positive pressure mode is more interesting than the recirculating one because the positive

pressure prevents the entrance of dust and other external pollutants, as well as expelling undesired Volatile Organic Compounds emitted by the objects.

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