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Effect of water wall prototype on air humidity

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Abstract. The presented document focuses on the effect of the water wall on air humidity (humidification and dehumidification of air). For the purpose of impact verification, a water wall prototype that was tested under laboratory conditions (climate chamber) was designed and built. Also a set of measuring sensors has been installed, these sensors are able to continually record air temperature and humidity and water temperature. In the case of air humidification, the water temperature and air temperature were equalized approximately after 2 hours and after 6.5 hours the air relative humidity reached 92%. This represents an increase in the specific humidity of 4.5 g/kg versus the initial state. The article also describes methodology and measurement of condensation ability of the prototype. In case of air dehumidification process, three different relative humidity was tested at the same air temperature. During the measurement periods, there was increasing the amount of condensate several times by increasing the relative humidity.

1. Introduction

The humidity of the indoor air is an important factor affecting the energy consumption of buildings, the durability of building elements and the perceived air quality. In summer, due to relatively high temperatures, their content in the outside air is significant, the higher the air temperature, the more it is able to absorb water. The air supplied to the interior is then, after cooling to an internal temperature, approximately saturated with water vapour, the relative humidity may be close to its saturation. In winter, due to low temperatures, their content in the outside air is low, because at low temperatures condenses or even freezes and fall to the ground. The air supplied to the interior after the heating to an internal temperature is dry, oftentimes the relative humidity falls below the 20%. The most common were indicated dry mouth and throat, also on the face, dry eye, lips, and also a cold [1]. Surveys show that the employees in office areas with and without air humidification suffer differently under the described symptoms caused by dry air. If air humidification is used, the discomfort is reduced by nearly half. In workplaces with air humidification, the discomfort caused by a dry respiratory tract is reduced by more than a third to 35 percent [2].

Indoor humidity depends on a several factors, such as sources of humidity, air flow, moisture exchange with a material or the state of water vapour in the outdoor environment. One of the sources of humidity can also be water elements, which are most commonly perceived as aesthetic elements. The design of water elements in the interior may vary, using different materials and shapes. The water wall when the water flows on solid material is a universal solution for existing buildings. The vertical position of the water wall does not require large spatial demands and brings the beauty of falling water into the interior. An environment containing water elements helps to reduce stress, increase the feeling of calmness and decrease heart rate and blood pressure, also improves concentration, memory and can lead to increased productivity [3].

To modification an indoor microclimate, the water wall can be used in two different ways. In the first case, the water wall is used for cooling and dehumidifying air in the space. The water film is cooled and its temperature is below the dew point, so a condensation process occurs. In the latter case, the water



temperature is the same as the air temperature in the room, so evaporation occurs, which increases the humidity of the air [4]. Similarly oriented research was realized at FRAUNHOFER Institute for Building Physics. This research presents the dependence of water temperature to the condensation ability of the water wall [5].

2. Experimental prototype of water wall

For the purposes of verifying the effect of the water wall on the indoor environment, an experimental prototype was designed to define its essential parts. There are several possibilities to create a water film, in this case it is a perfect overflow, the water falls over the overflow edge, flows down the glass and forms a continuous water film.

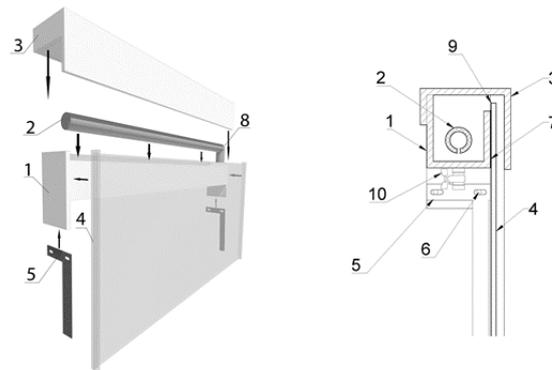


Figure 1. Arrangement scheme of main components of the upper part of prototype and section:

collection tank (1), perforated pipe (2), a cover (3), glass pane (4), supporting metal structure (5), screws (6), silicone adhesive (7), water supply (8), spillway edge (9), ball valve (10).

The formation and thickness of the water film affects, among other things, the geometry of the upper part of the water wall (Fig. 1). The upper part consists of a water collection tank of rectangular shape made from polypropylene material by melt-welded in order to achieve waterproof. A water supply pipe that is perforated is inserted into this tank. The downward perforation allows a steady flow of water into the tank to create a uniform water film across the whole width of the water wall. The effective water film area is 1m². The overflow edge is formed by a glass plate which is connected to a collecting tank with a silicone adhesive. The overflow edge must be in the horizontal position. In order to achieve a united appearance of the water wall and at the same time, to prevent unwanted evaporation of water, the collecting tank is covered by a cover.



Figure 2. Final water wall prototype.

3. Methodology of measurement

Experimental verification of hypotheses take place under laboratory conditions in the climate chamber where steady conditions can be maintained, the temperature range is from -20°C to $+125^{\circ}\text{C}$ and the climatic range is from 20% to 95%. Its inner dimensions are $3.95 \times 1.60 \times 2.85\text{m}$ and the volume of the air in the chamber is 18.012 m^3 . The chamber walls are made of stainless steel, so during the experiment there isn't exchange of mass between air and chamber.

The set of sensors has been installed in the chamber. The temperature and relative humidity sensors are connected via the AHLBORN control unit. The AMR Win Control software was used to obtain and collect measured data. This provided continuous recording of the measured values in a 5 minute time step. Two sensors measured the water temperature in the lower tank and two sensors in the upper tank. From these sensors the average water temperature for the lower and upper part was determined. In front the water film, two sensors were placed to measure the temperature and the relative humidity of the air, and one behind the glass. The location of the sensors is shown on figure 3.

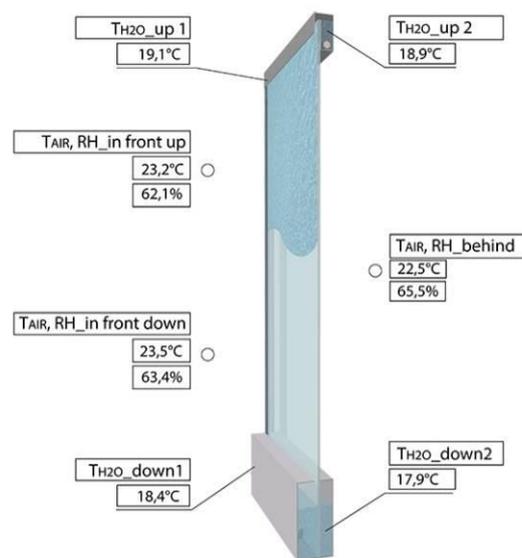


Figure 3. Set of measuring sensors.

For the measurements of influence of water wall to dehumidification and cooling of the indoor air, the system with using a measuring cylinder and weight increment measurement (fig. 4) was proposed using the RADWAG laboratory scale to an accuracy of 0.01g . This modification made it possible to accurately and continuously record the increase in the condensate formed on the water film. Also a plate exchanger was added to the water wall system which allowed a constant water temperature in the system around 14°C . After the experiment is started, the parts of the water wall are flooded, and water needs to be added to the level of the overflow created in the measuring cylinder. Then, during the experiment the water from the lower collection tank flows into the measuring cylinder. From it the water is supply into the upper part of the water wall by the pump and cooled by the plate exchanger. The shut-off valve is used to control the flow rate velocity and the flow meter are used to monitor accurately flow rate. During the running of the water wall, it has been found that the optimal flow rate is from 300 l/h to 500 l/h , at lower velocity, water film was not formed in whole width and at higher velocity, water bounced off the water film.



Figure 4. Measurement system of water wall.

4. Results and discussion

4.1. Evaporation process

Figure no. 5 shows the dependence of the monitored parameters during the evaporation process. The experiment took 6.5 hours, in two repetitions at a flow rate of 300 l / hr. The climate chamber was inactive, the experiment focused on the interaction of the water wall with a volume of air, with the possibility of excluding sorption of the surrounding components. The graph shows that the water temperature (TH2O) and air temperature (TAIR) equalled 2 hours after the experiment start.

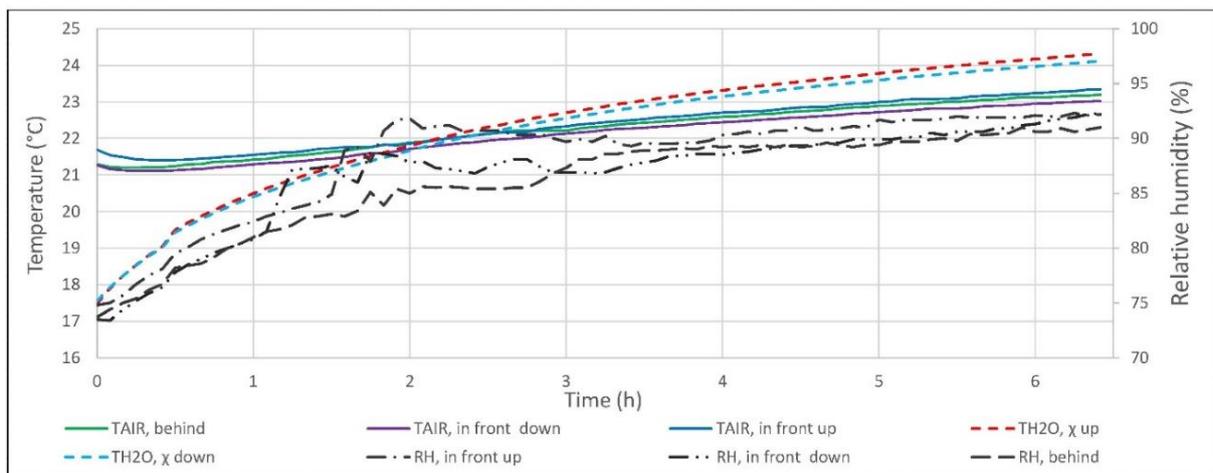


Figure 5. Evaporation process from water from water film.

At the beginning of the measurements, the water temperature (TH2O) had an average value 17.52 °C. The average air temperature (TAIR) was 21.42 ° C and a relative humidity (RH) was 74%, which represents a specific humidity 11.67 g/kg. At the end of the measurement cycles, the water temperature

(TH2O) reached 24.21 ° C, the air temperature (TAIR) was 23.19 ° C, the relative humidity (RH) was 91.83% and the specific humidity was 16.17 g/kg. Compared to the initial state, the specific humidity increased by 4.5 g/kg.

4.2. Condensation process

During the second series of the measurements aimed at determining the amount of condensate on the water film, the climate chamber was used actively, that provided steady boundary conditions (Figure 6) during the experiment. Two measurements were made, the mean water temperature (TH2O_down) in the lower tank was 14.58 ° C, then it was cooled by the plate exchanger to 13.86 ° C (TH2O_up), the mean air temperature (TAIR) was same in both cases 25.73 ° C. In the first case, the mean relative humidity (RH case no.1) was 58.83%, in the second case the mean relative humidity (RH case no. 2) was 73.99%.

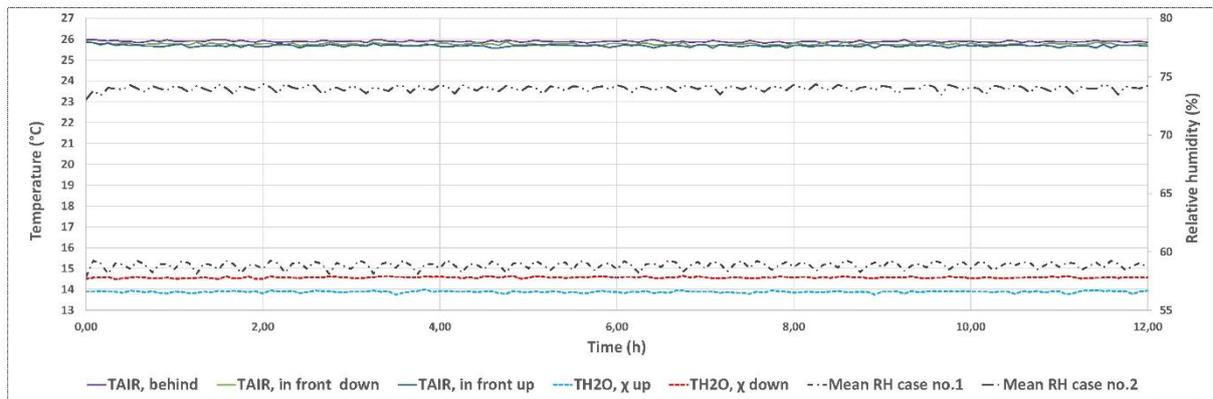


Figure 6. Boundary conditions in the climate chamber during the experiment.

The graph (Fig. 7) represents the courses of condensation on the water film in time dependence. In the first case, when the mean relative humidity was 58.83%, the hourly gain of condensate was 21.86 g/hr. In the second case, at the relative humidity of 73.99%, the hourly increase of condensate was 148.81 g/hr. The difference between mean relative humidity in the first and second cases is 15.16%, the hourly difference in the weight of the condensate is 126.95 g / hr. Compared to the second case, where the condensate gain curve is almost linear, in the first case the curve is stepped. This is caused by a low hourly gain of condensate.

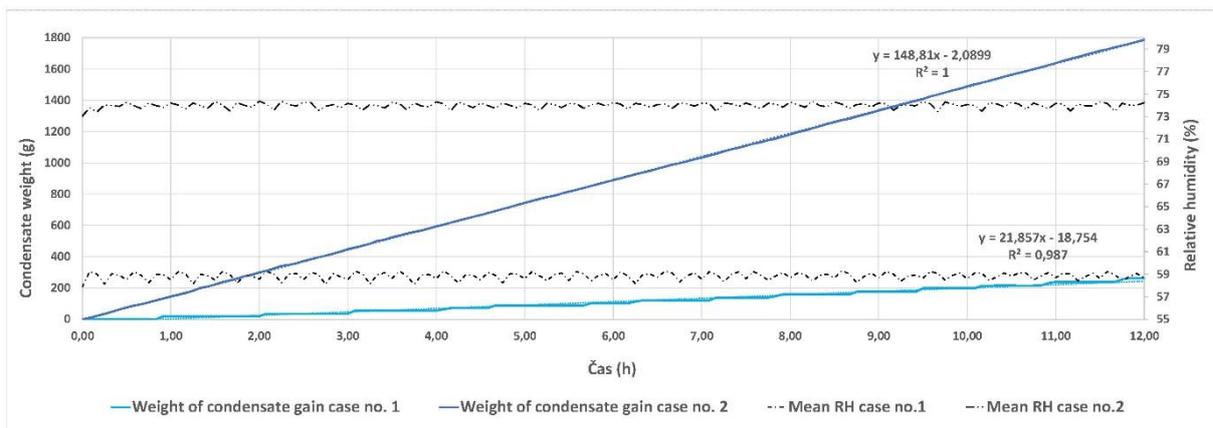


Figure 7. Courses of weight gain of condensate at constant air temperature.

5. Conclusion

Regulation of air temperature and humidity is a basic priority and a requirement to achieve an optimal environment. In addition to using conventional systems such as air conditioning systems, also water

walls may be used for this purpose. The article showed the influence of the use of the water element in the interior of the buildings on the parameters of the indoor microclimate. Using the climate chamber to measure its impact has proven to be appropriate for laboratory analysis. The first part of the paper demonstrates the effect of the water wall to humidification the indoor air. During the experiment, the relative humidity increased from 74% to 91.83% and air temperature from 21.42 ° C to 23.19 ° C, it represents an increase in specific humidity of 4.5 g / kg. In the second part, the ability of the water wall to reduce the relative humidity of the air by the condensation process was presented. Supplementing of the original prototype by the plate exchanger and continuously weighing of the condensate exactly specified the results of laboratory experiments. During stationary conditions (water temperature, air temperature), the influence of relative humidity on the amount of condensate on the water film was investigated. With the mean relative humidity of 73.99%, the condensation ability of the water wall was 148.81 g / kg, that is more than 6.5 times higher the condensation ability of the air humidity on the water film compared to a relative humidity of 58.83%. The presented contribution is part of the doctoral study and it is necessary to define and verify other hypotheses for determination of the impact of the water wall under different boundary conditions.

6. References

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