DISCUSSION / DISCUSSION

Reply to the discussion by Leong et al. on “Assessment of the use of the vapour equilibrium technique in controlled-suction tests”¹

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The authors would like to thank the discussers for their interest in our paper and their valuable comments. The discussers have highlighted our conclusion by providing experimental data related to the difficulty in controlling total suction when hastening the equilibrium condition of vapour transfer by using a magnetic stirrer in their reference salt solution reservoir. Their data complement the approach followed by the authors using numerical results, even though they apply a different experimental procedure — the authors use a forced convection system to facilitate vapour transfer. Nevertheless, the authors agree with the discussers that these hastening procedures could possibly result in air pressure and temperature differences created along the constant mass circuit that would induce variations in the relative humidity, which is supposedly controlled by the reference salt solution reservoir.

With this being stated, the authors would also like to present some experimental results to provide further evidence of what they concluded using numerical simulations. Dueck (2004) studied the influence of air pressure changes in a forced convection circuit of vapour — driven by an air pump — and their consequences on the applied relative humidity. Figure R1 shows a scheme of the experimental setup and the evolution of differential air pressures between two points of the circuit (upstream and downstream of the filter stones that transfer vapour to or from the soil). The point upstream of the filter is near the reference reservoir (“ref” in the figure), while the point downstream of the filter is close to the aspiration branch of the air pump (“p” in the figure) and is subjected to a pressure drop. After vapour equalization, the pump is turned on and air is forced through the circuit. At 67 min, the speed of the pump is rapidly increased and is then reduced from 78 min on. The consequences on the evolution of the relative humidity at the same two points of the circuit are shown in Fig. R2. As observed, downstream point “p” near the pump undergoes important relative humidity changes due to air pressure drop,

while upstream point “ref” is buffered by the reference salt solution reservoir.

The mass rate transfer under isothermal conditions of vapour by convection with a known air flow rate has been expressed in terms of the differences in mixing ratio (mass of vapour per unit mass of dry air) between the reference salt solution reservoir and the soil (see for example, Jotisankasa et al. 2007). As a consequence, an expression to account for the effects of air pressure variations on the relative humidity can be proposed based on the assumption under vapour equilibrium and isothermal conditions that the mixing ratio, x , set by the reference salt solution is also set at another point of the constant mass circuit. Assuming vapour and dry air as ideal gases and at the same temperature, the following expression is obtained for the mixing ratio: $x = M_{mw}u_v / (M_{mda}u_{da}) = 0.622 u_v / u_{da}$, where M_{mw} and M_{mda} are the molecular masses of water and the dry air mixture, respectively; u_{da} is the dry absolute air pressure; and u_v is the vapour pressure. The following expressions are obtained between the relative humidity reference reservoir, $h_{r\text{ref}}$, set by the salt solution, and another point of the circuit, h_{rp} ,

$$[R1] \quad \begin{aligned} u_{vp} &= u_{v\text{ref}} \frac{u_{dap}}{u_{daref}} \\ h_{rp} &= h_{r\text{ref}} \frac{u_{dap}}{u_{daref}} \end{aligned}$$

where u_{vp} and $u_{v\text{ref}}$ are the vapour pressures at points “p” and “ref”, respectively; u_{dap} and u_{daref} are the dry absolute air pressures at points “p” and “ref”, respectively; $h_r = u_v / u_{v0}$ is the relative humidity, and u_{v0} is the common saturated vapour pressure.

The last expression in eq. [R1] is used to simulate the variations in relative humidity at downstream point “p”, h_{rp} , which are plotted in Fig. R2. The absolute pressure at point “ref” is fixed at $u_{daref} = 101.3$ kPa, while absolute pressure changes at point “p”, u_{dap} , are estimated from

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Fig. R1. Experimental setup and time evolution of differential air pressures between upstream point “ref” and downstream point “p” (experimental data from Dueck 2004).

Fig. R2. Time evolution of measured and simulated relative humidity at two points of the forced convection circuit: upstream point “ref” near the reservoir and downstream point “p” close to the pump (experimental data from Dueck 2004).

Fig. R1: $u_{da,p} = 101.3 - \Delta u_{da}$ kPa. If both upstream and downstream absolute pressures are affected — for example, $u_{da,ref} = (101.3 + \Delta u_{da}/2)$ and $u_{da,p} = (101.3 - \Delta u_{da}/2)$ kPa — equivalent results are obtained. As observed in Fig. R2, the simulated points follow the general trend of the measured variations in $h_{r,p}$, although they display slightly larger values. An equivalent simulation is used to estimate the relative humidity at upstream point “ref”, $h_{r,ref}$, using $h_{r,p}$ data. In this case, the simulated points do not follow the stable tendency of the relative humidity experimental data, which are buffered by the proximity of the reference salt solution reservoir. Nevertheless, the initial small drop, the next small increase at around 33 min, and the smooth peak detected at 67 min are captured in their trend.

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