The Moisture-Buffering Capacity of Enclosures

Equilibration is a continuous, dynamic interaction between an object (its surface, perimeter, and its core) and its environment (both its microclimate and the surrounding macroclimate). The amount of time it takes for an object to equilibrate to the relative humidity depends on several variables; the inherent properties of the object, the hygroscopic nature of the material, the dimensional characteristics, the surface exposure to the environment, and the ambient temperature all influence the rate of moisture equilibration. Researchers at IPI have documented that enclosures can also play a significant role in determining the rate of moisture equilibration.

The effect of enclosures can be imagined like the nesting Russian dolls, or matryoshka. The object (which inherently has a interior core and exterior perimeter) nestles inside the enclosure, which is placed inside a room, which is part of a larger building, which is located in a certain climate region. Each of these "levels" – from the core of the object to the outdoor weather - can potentially have distinct environments, with temperature and relative humidity values different from the next. At IPI, comparison of outdoor and indoor data is used frequently to evaluate the nature of the building envelope, the performance of the mechanical system and the scope of viable, alternative operation scenarios. For this article, however, we are interested in how enclosures impact moisture equilibration and will focus on the moisture relationships between the object, its enclosure, and the macroenvironment. Because certain enclosures have the capacity to buffer moisture (and therefore slow the diffusion of water vapor from the surroundings), the environment inside the enclosure can differ significantly from the environment outside the enclosure. This distinct, secondary environment immediately surrounding the object is referred to as a ***microclimate***, while the larger environment of the room is called the ***macroclimate***. How much the microclimate differs from the macroclimate depends on the enclosure material's permeability and capacity for moisture adsorption and desorption, the characteristics of the enclosure design (i.e., tightness of its seal), and, to a certain extent, the hygroscopic nature of the collection object inside the enclosure.

Certain enclosures slow the rate of moisture equilibration.

As discussed in the previous article, the process of moisture equilibration is significantly slower than thermal equilibration. Even without the buffering-effect of enclosures, materials freely exposed to environmental changes required days or weeks to reach 50% equilibration with the new environmental conditions. When researchers at IPI exposed a variety of photographic materials in different housing- enclosure configurations to humidity changes and monitored the moisture response of the materials, the resulting data demonstrated that certain enclosure types slow the rate of moisture equilibration even further.

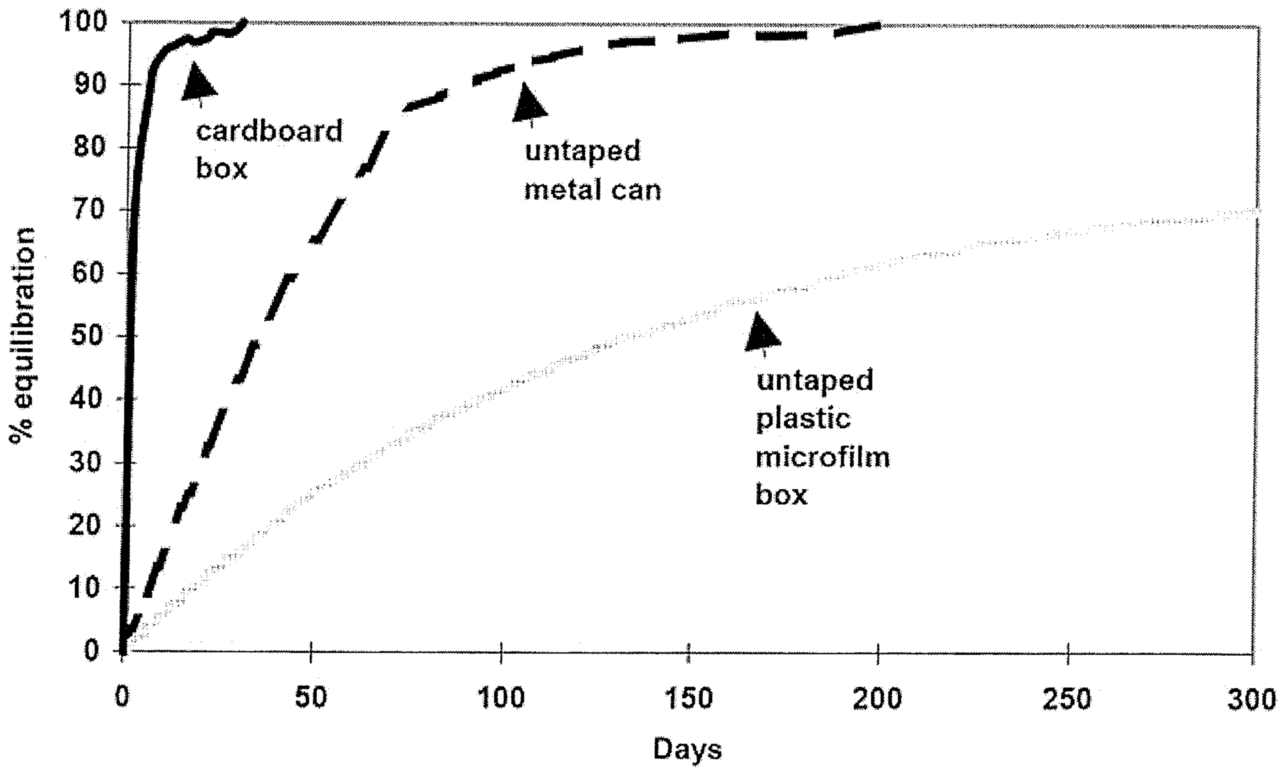

Figure 1: Moisture equilibration rate at 21°C from 20% to 50% RH for 100-ft. roll in various enclosures.

Figure 1 shows the moisture equilibration rate for three 100 ft. motion-picture roll films stored in different enclosures: a cardboard box, a metal can and a plastic box. Each material-housing configuration was preconditioned to 21°C (70°F) and 20% RH in climate-controlled chambers and then the relative humidity was raised to 50% RH (temperature was held at 21°C). Even for the fastest equilibrating configuration (the film in the cardboard box), it took ***fifteen days*** for the film to reach 90% equilibration. The other two configurations, with less permeable enclosures, needed significantly longer to reach the same level of equilibration. The roll in the metal can reached 90% equilibration only after several ***months*** and the roll in the plastic can needed ***over one year*** for 90% equilibration. Because the metal and plastic cans significantly slowed the diffusion of moisture into the enclosure, much more time was required for the film to fully adjust to the higher humidity condition.

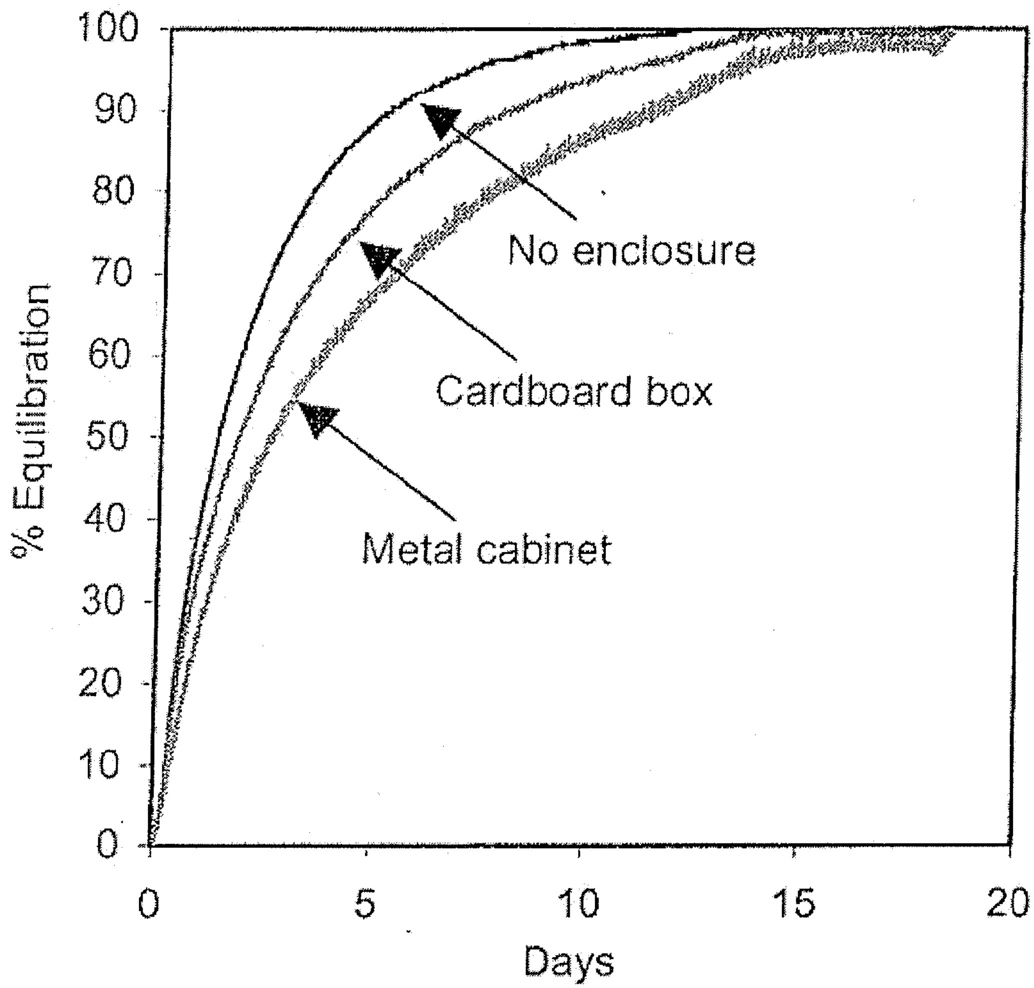

Figure 2: Moisture conditioning rate from 20% to 50% RH at 20°C for a stack of sheet films in three configurations (1) without container, (2) inside a cardboard box, and (3) inside a metal cabinet.

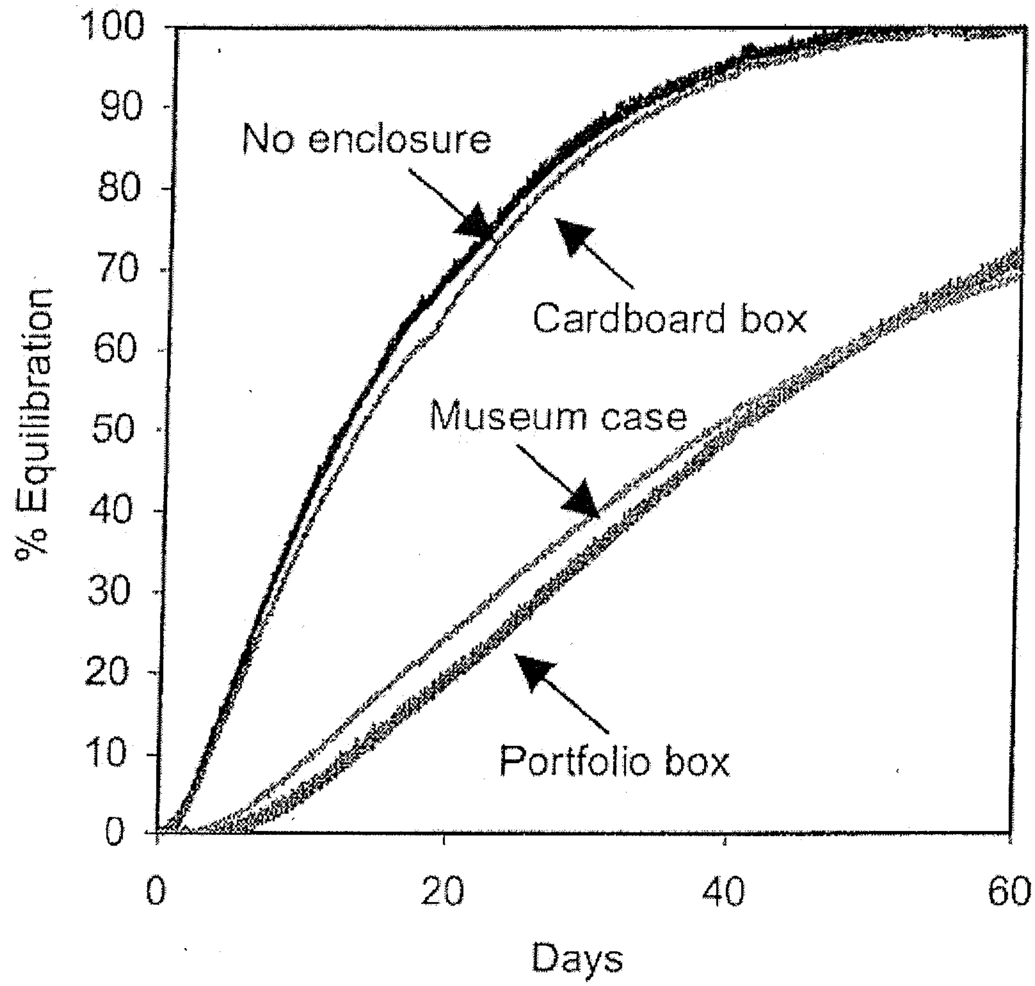

Figure 3: Moisture conditioning rate from 20% to 50% RH at 20°C for a stack of 15 mounted photographs stored (1) without enclosure, (2) inside a cardboard box, (3) inside a museum case, and (4) inside a portfolio box.

Similar observations were made for stacks of sheet film and mounted photographs. Figures 2 and 3 plot the time to equilibration when the samples were exposed to a one-time humidity change from 20% RH to 50% RH at 20°C (68°F). The stacks of 175 4" x 5" sheet films were each inserted in individual paper envelopes and prepared with three housing configurations: one without an enclosure, one inside a cardboard box and another inside a metal cabinet. The cardboard box slowed the moisture equilibration rate slightly, but the slowest rate was observed for the stack in the metal cabinet, almost doubling the time required to reach 90% equilibration without an enclosure (~11 days inside the metal cabinet compared to ~5 days outside the enclosure). Less moisture-buffering capacity was demonstrated by the cardboard box containing the mounted photographic prints, whose equilibration rate was nearly identical to the rate of the print-stack without an enclosure. (Notice how the equilibration curves of these two configurations overlay one another in Figure 3). The museum case and the portfolio box, however, had greater moisture-buffering capacity and both extended the time required for the mounted photographs to reach 90% equilibration from one month (without an enclosure or in cardboard box) to over three months (in both the museum case and the portfolio box).

Certain enclosures buffer fluctuations from the macroenvironment.

The impact of enclosures on the rate of moisture equilibration is an indication that the enclosure modifies the environment around the collection object. As stated earlier, the amount the microclimate differs from the macroclimate depends both on the nature of the material as well as the moisture-buffering capacity of the enclosure. To understand this relationship further, researchers at IPI designed an experiment to observe the relative humidity at each level of the relationship between the object, enclosure, and ambient space. RH was monitored in the macroclimate (the RH we are accustomed to seeing and measuring) as well as in microclimate (the space within the enclosure) and within the object itself (at the core of the object).

Two stacks of twelve mat-board mounted photographic prints were placed in two typical museum boxes: one in a drop-front cardboard document box and the other a Solander museum case. Holes were cut into the mounts at the center of each stack so that a datalogger would fit, concealed, within the stack of photographic prints. One data-logger was inserted inside the stack of mounts, a second was placed in the open space of the enclosure (next to the stack) and a third monitored the outside conditions.

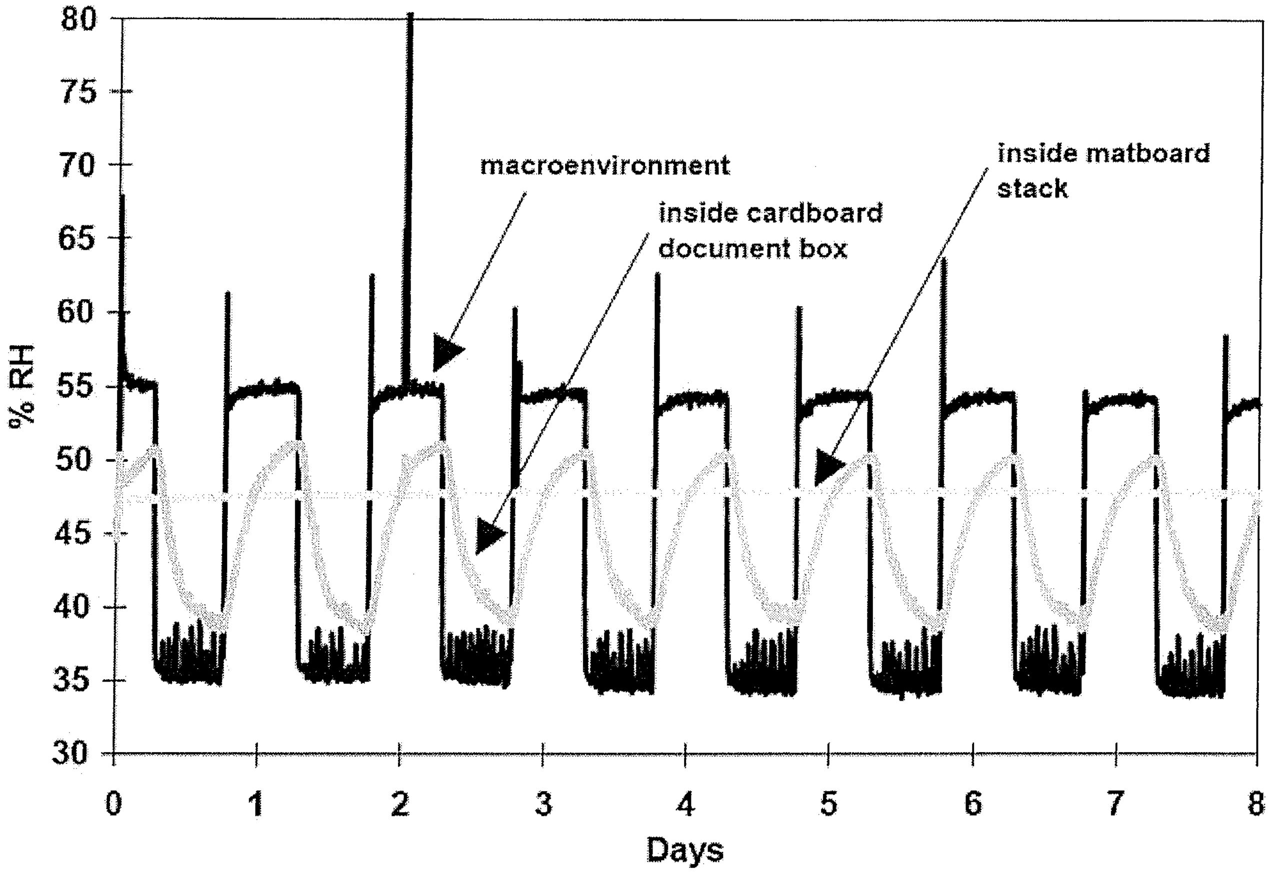

Figure 4: Impact of daily 45%±10% RH cycling on the microenvironment inside a cardboard document box at 21°C.

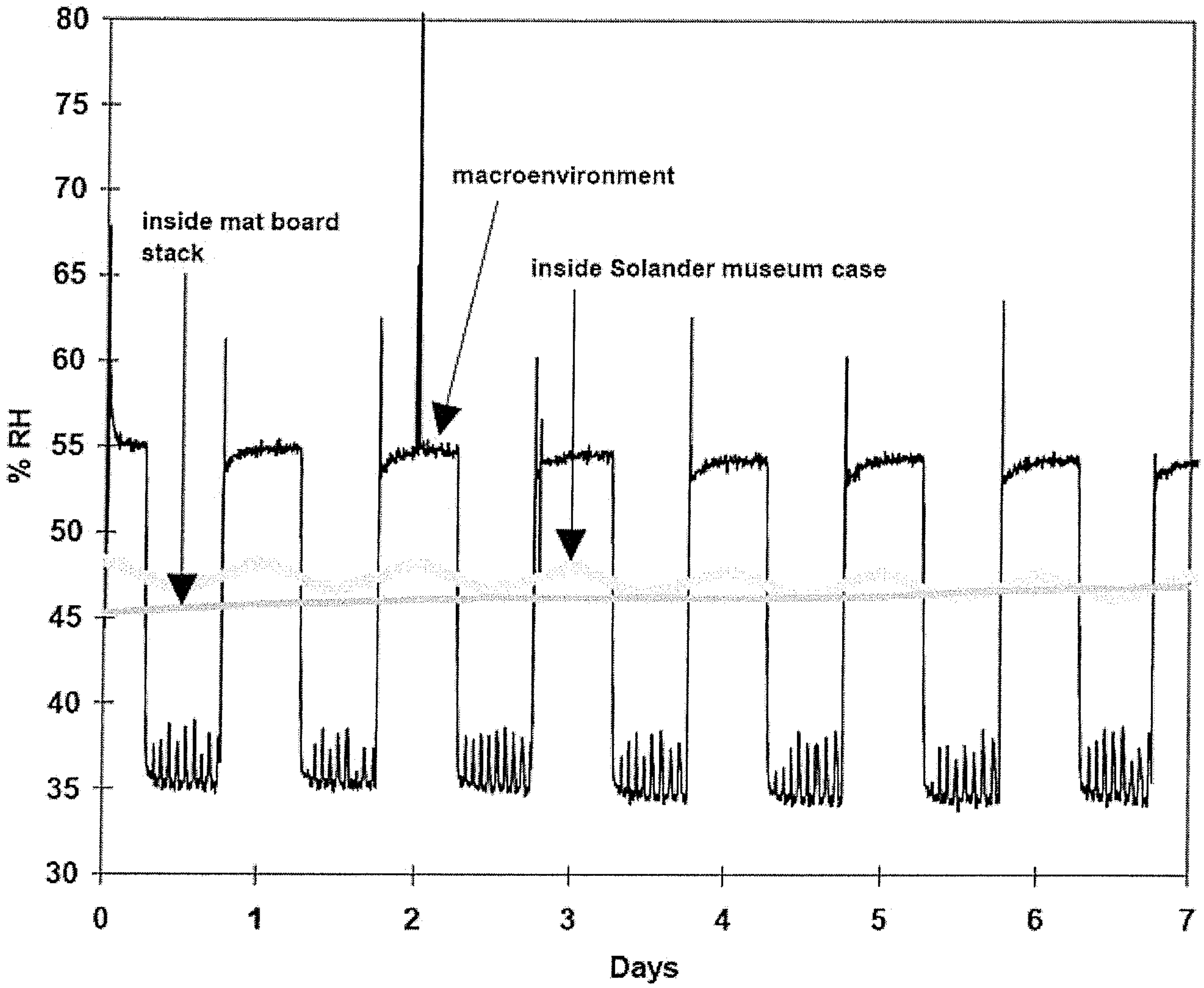

Figure 5: Impact of daily 45%±10% RH cycling on the microenvironment provided by a Solander museum case at 21°C.

Figures 4 and 5 illustrate the relative humidity levels when each configuration was exposed to daily RH cycles of 45±10% RH at 21°C (70°F). In the cycle, each humidity condition (~55%RH and ~35%RH) persisted for 12 hours. Although the cardboard box demonstrated less moisture-buffering capacity than the Solander museum case, figure 4 shows that the humidity changes of the macroclimate were still mitigated by the cardboard enclosure. The microclimate relative humidity mimics the macroclimate relative humidity but, during the 12 hours at the new humidity condition, the %RH within the cardboard box never fully adjusted to the changing %RH of the macroclimate. Notice the relative humidity within the core of the stack remained stable, slightly above 45%RH throughout the cycling macroclimate conditions. Figure 5 illustrates that even less fluctuation occurred within the Solander museum case; inside the case, the 20% RH fluctuation in the macroenvironment was translated into less than 5% fluctuation in the microenvironment. The relative humidity at the center of the stack of photographic prints, similar to the stack in the cardboard box, remained largely unchanged.

When we consider the magnitude and duration of these relative humidity changes (with a range of 20% RH, lasting 12 hours each) and we observe that full equilibration was not reached within the experimental microclimate, we can start to put into perspective the relative humidity fluctuations often observed in real-world collection spaces. Temporary or sporadic humidity fluctuations, resulting from changes in outdoor humidity levels or HVAC system functionality, are generally shorter in duration and smaller in magnitude. Given the generally slow rate of moisture equilibration and the moisture- buffering capacity of certain enclosures, most humidity "events" observed on graphs of macroclimate relative humidity will not have significantly affected the collection objects.

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