Microclimate Control in Museums

Ask a climatologist, and he will tell you that a microclimate means the particular local weather pattern of a city or region. Ask a winemaker, and your answer will be the climatic characteristics of his vineyards. A heating and cooling engineer in a museum might describe the conditions he creates and controls within a building or a room as microclimates, but the conservator in the same museum would be talking specifically about the environments created in display cases, storage boxes, and glazed picture frames.

Conservators have long been aware that the environment surrounding the objects in their care has the greatest effect on its condition. More exactly, it is the thin layer of air immediately surrounding the artefact (the microenvironment) that interacts with the object. Moisture, dust, corrosive pollutants, even the oxygen in the air can react with an object to create chemical changes and mechanical stresses. Control the makeup of the microenvironment and you can limit the air's interactions with the artefact. The easiest way to do this is to create a controlled microclimate in the general area surrounding the object.

For the purposes of this article, a microclimate will generally refer to a conservator-acceptable environment that is created and maintained in a display or storage enclosure. This can be accomplished by:

- Using the building's HVAC system to provide a whole gallery environment that permeates into the cases
- Using passive microclimate control, which relies on a quantity of buffering material (usually some form of silica gel) and a very tightly sealed display case
- Using an active microclimate control device that uses a mechanism to maintain constant relative humidity in a reasonably well sealed display case.

Passive microclimate control has been a mainstay of preventive conservation techniques in museums for much of the past thirty years. Recently, an increasing number of conservators, designers, and architects have been specifying active microclimate solutions for new institutions, renovations, and individual display case installations, and facilities managers are taking a keen interest in an area that was once seen as the limited concern of conservation staff.

If your museum is not already using some sort of microclimate control (passive buffering or active system), you can expect to see it soon. This article will introduce you to both passive and active microclimate control, compare them, and explain some of mechanical concepts behind active microclimate control systems. With this information you will be better able to advise your institution on the installation of appropriate systems.

The Case for Microclimate Control

For years, conservators have pleaded, cajoled, and threatened their museum partners to create gallery climate conditions that will better protect the artefacts in their care. Their concern has the creation and maintenance of stable relative humidities, as the direct effects of temperature on artefacts is relatively unimportant. While changes in temperature may, in theory, cause expansion or contraction in an artefact, the actual amount of change is usually microscopically small, and essentially inconsequential at normal temperatures. However, many artefacts (especially organic materials and composites) are especially prone to damage from internal stresses caused by changes in their moisture content.

A fundamental aspect of climate control is that variations in air temperature will affect in the relative humidity levels, even though the absolute moisture content of the air remains the same. Constant relative humidity may be an admirable goal, but temperature variations, along with building envelopes, ventilation demands, limits of machinery, and other factors may make the provision of ideal conditions difficult, or just plain impossible. Where tighter standards than those that could be created by the gallery environment have been needed, conservators have experimented with the creation of closely controlled microclimates in the specialized display cases surrounding sensitive artefacts.

As in the larger world, the most important vector of change in these miniature enclosed environments was found to be the flow of air in and out of the structure. Even well-sealed exhibition cases were found to have measurable air flows. As in larger structures, the rate of leakage was seen to be clearly dependent on the differentials between the conditions inside and outside the enclosure, as well as the size and location of the openings.

In almost all situations, small cracks, holes, and voids in gasketing, driven by “stack pressure” (caused by differences in air density between interior and exterior), were found to be enough to drive a surprising amount of air through the enclosure. A practical result is that while a modern, tightly sealed case can have an air exchange rate as low as one tenth of an air exchange per day when originally installed, the slightest change in alignment or gasketing can easily create a leakage rate ten times as great. The reality is that most cases leak, and microclimate control techniques are very dependent on leakage rates.

Just as a building’s environment is affected by the weather outside, a display case’s microclimate is influenced by all the conditions in the gallery that surround it. Substantial differences in humidity will increase the effects of case leakage, and while a well sealed case may prevent the influx of air, the interior of a case cannot be isolated from temperature changes. Heat can enter or leave the case by radiation or conduction. As noted above, the resulting minor changes in display case temperatures are usually of little concern to the conservator, but the changes in relative humidity (as a consequence of changes in air temperature) can have serious consequences for some artefacts.

Given a tightly sealed display case in a climate controlled gallery, one can expect the microclimate in the case to drift slowly away from its initial humidity over an extended period. To provide longer term stability, conservators began to demand tightly sealed show cases, and developed their own methods to maintain constant humidity, using passive buffering (silica gel) and miniature microclimate control devices.

Protecting Display Cases using Passive Buffering

Long before studies determining case leakage rates were undertaken, conservators understood that creating a sealed case would protect artefacts from air-borne pollutants. It was also known that including some sort of buffering (organic materials such as wood, cloth, or paper) would provide some control over humidity variations. The basic principle is that a buffer will release or absorb moisture from the air to maintain equilibrium. Given a large enough buffer, long term constant conditions can be maintained in a sealed enclosure.

Early attempts at providing long-term humidity buffering (beginning in the 1930’s) involved the use of saturated salt solutions. As the saturated salts could themselves be harmful to the objects, complex systems had to be developed to move the humidity buffered air from the salt to the display chamber containing the object. Needless to say, relatively few of these systems were constructed or used.

In 1959 silica gel was first recommended as an agent for buffering humidity changes. Silica gel was patented in 1919, and had been used extensively in the Second World War as a catalyst for chemical reactions and as a desiccant to keep machinery dry. New formats of silica gel (such as PROSorb) are far more effective. The use of silica gel as a buffer for humidity changes is unique to museum applications, as it uses only a small portion of the adsorptive capacity of the material. As a consequence, providing an appropriate amount buffering, and regular monitoring and reconditioning of the silica gel buffer is critical to its effectiveness.

Passive buffering can be very effective. Unfortunately, any combination of a poorly designed display case, a high air leakage rate, a very large showcase, or inadequate monitoring and reconditioning make humidity buffering with silica gel an unreliable solution.

Inventing Active Microclimate Control Systems

Faced with the successes and difficulties of supplying passive microclimate control systems, efforts were begun in the 1970's to develop alternative methods using mechanical devices to add and subtract the very small amounts of moisture needed to maintain a constant humidity level. The engineers and conservators developing the early microclimate control found many challenges. Tried and true concepts of humidity control needed radically new means of application. Why did the development of microclimate control prove to be such a challenge?

The basic principles that are used to build and operate a large HVAC system hold true for a tiny microclimate system. The difference is one of scale, and the differences are unexpected and dramatic. HVAC systems engineers measure airflow in cubic meters per minute, where torrents of air are distributed through complex ductwork. Microclimate control systems typically use flows that are measured in mere liters per day, distributed through small tubes or hoses. Display case entry flows that correspond to a gentle breath of air, and moisture removal rates of a few drops per hour are the norm for microclimate control.

Rather than using large blowers, steam generators, hundreds of meters of ductwork and large compressors, as one would find in a large HVAC system, the first successful miniature microclimate devices used materials from the electronics industry: small computer cooling fans and thermoelectric cooling devices to deliver miniscule quantities of moisture modified air to cases. Unlike previous efforts using the output from industrial machinery, these small and seemingly ineffectual devices worked!

Of course, another reason they worked was that massive HVAC systems were already maintaining relatively stable conditions in the air surrounding the display cases, so all the microclimate system had to do was to control a very small quantity of air in the display case. The major benefit of using a “nested” system was that facilities managers now needed only to provide generally acceptable humidity levels for human comfort.

This led to immediate savings in operating costs, and ultimate to savings in capital expenditures too (for improving building envelopes, and replacing equipment). By using a microclimate system to “trim” the case humidities, building HVAC systems could be used to create temperatures, humidities, and fresh air supplies that were comfortable for visitors (the job they were designed to perform), rather than being tuned and tweaked to provide a conservation quality environment in the entire gallery. Facilities managers were freed to create conditions that balance out both cost savings and comfort. Temperatures and humidity levels could be allowed to vary from season to season, while the microclimate systems would continue to provide unchanging humidity levels in the cases.

Benefits of Active Microclimate Control

Savings for operating costs can be enormous. This is primarily a reflection of the cost of energy used to humidify / dehumidify the air, and the difficulty of recovering this energy as stale air is exhausted and fresh air is brought in. Studies show that the costs of providing humidity control increases dramatically as tighter setpoints are maintained. In general energy costs per square foot are doubled for every halving of set points. For example, it costs twice as much to maintain a building at +/-5% as it does at +/-10%, and this is doubled again if you try and maintain +/- 2%. Fortunately, the inverse is true, and relaxing humidity set points can provide substantial savings.

Operating Principles of Active Microclimate Systems

Active microclimate devices are generally used to provide humidity control on sealed enclosures such as display, storage cases, or sealed archive rooms. Air exchange rates of less than four air changes per day are typically found in these enclosures. (Some of the newest display cases typically have leakage rates of less than 0.1 air changes per day when installed). Air flow demands for sealed enclosures are surprisingly small: for a microclimate device to compensate for the leakage through a one cubic meter display case that is leaking at one air change per day, the microclimate device needs to supply less than a liter of air per minute. Contrast this with typical gallery air exchange rates in excess of over four air changes per hour.

To deliver this tiny flow of air, some devices use miniature air pumps, others small fans, but generally all these devices deliver air via hoses or pipes. Some devices recirculate display case air through supply and return ducts, in others a single small input hose provides filtered positive pressure air. Positive pressure devices keep the showcase slightly pressurized and in addition to controlling the humidity, the positive pressure keeps out pollutants and dust.

As mentioned above, many of the mechanisms in a microclimate device are similar in operation to those in a large HVAC system. The greatest differences are to be found in the methods of modulating the air stream. As the humidity control input air flows are much, much smaller, humidity modification can be done using processes that would be impractical to manage on a larger scale, such as bubbling supply air through a body of water.

To maintain a target humidity in a museum gallery, an HVAC system will add an appropriate amount of moist or dry air, mix the added air into the existing room air, and modulate this flow as the desired relative humidity level is achieved. Virtually all building HVAC systems work on this “compensating” principle of climate control, as do some older microclimate devices. It is important to note that this method of humidity control is only practical where each unique enclosure to be controlled is treated as a single zone with its own sensor and controller.

However, multiple enclosures can be treated using a single remotely located microclimate generator. As the showcases have virtually no leakage, a relatively small flow of air, preconditioned to the target humidity, is all that is needed to maintain a constant humidity level in the showcase. Given that all the showcases can be reasonably expected to be at the same temperature, a single microclimate generator producing a moderate flow of air through a network of positive pressure tubes can maintain constant humidity in dozens of showcases or storage cabinets. Humidity levels in the enclosures are maintained by completely displacing and replacing the existing air in the enclosure.

Displacement systems are possible only in the realm of microclimate control, where enclosures have a total of volume of a few hundred liters within a protected gallery. Inputs for conditioned air into treated cases are not louvers, but tiny holes the diameter of a pencil. A displacement system can never overshoot the humidity settings. Safe operation is easy to maintain- the constant flow of modified air is simply stopped if the input goes out of range, and well-sealed enclosures will maintain stable conditions for days.

This constant flow of air in an active microclimate device offers a further advantage, as it breaks up stratification due to density differences in the display case. This offers a substantial advantage when compared to passive buffering, especially in large showcases, where humidity modification throughout the case must be accomplished by diffusion of air out from the silica gel mass.

Although the output from an active microclimate device is miniscule when compared to an HVAC system, the power of a microclimate device when compared to a passive system is equally dramatic. (Think of the differences between a searchlight, a battery powered flashlight (UK torch), and a skylight. A flashlight cannot compare in power to a pulsed Xenon searchlight (as a microclimate device's output is a fraction of an HVAC system). However, there is a larger gulf between the variable and diffuse light from a skylight and the controllable, focused and efficient source of light offered by a simple flashlight.) Even a small active microclimate system can effectively maintain constant humidity in a display case that would quickly overwhelm the capacity of a silica gel buffer. This becomes more pronounced as enclosures get larger.

Microclimate control devices come in a variety of sizes, from miniature devices (the size of a shoebox and usually installed in a showcase) to remotely located standalone units (as big as a household refrigerator). Large units can be located hundreds of meters away from the showcases, and will supply many cases in a gallery.

Potential Problems of Microclimate Systems

Microclimate control is neither a universal nor a care-free solution. While these systems are generally designed and built to be quite robust, the devices must be correctly monitored and maintained. This is easily accomplished by scheduling, and made more convenient by the addition of indicators, alarms, and connections to building management systems now offered on most active microclimate devices.

Miniature devices are easy to install, needing only a source of power, an access panel and a little ventilation. Their components are miniature and often custom built, and in most cases, they need to be close to the showcase. Reservoirs must be maintained, and units should be inspected regularly.

Larger centrally-located units are built of industrial components, and are very robust. Central units are usually connected to plumbing systems. They utilize an air distribution system (usually a trunk and branch piping system) to deliver air from a machine room or closest into the showcases. While the piping is relatively easy to install and balance, integration into the building can be a challenge, especially if such an installation is not considered at the outset of a museum expansion or renovation.

Microclimate and Facilities Managers

Is microclimate technology really something new for facilities managers? Very few challenges of active microclimate control are different from those presented to facilities managers for many years. Perhaps the biggest difference is simply the origin of the system. HVAC systems are specified by mechanical engineers working with architects. Microclimate systems are usually instigated by museum designers, showcase fabricators, or conservation staff (often given responsibility for maintaining the microclimate generators). This is changing very slowly.

While the impetus for researching and creating active microclimate control may have been willingly generated by the conservation community, the responsibility for maintaining microclimate control has been only grudgingly accepted. Conservators would rather spend their time caring for their artefacts than contacting suppliers, refilling reservoirs, or recording data. A few conservation departments have now realized that competent assistance in maintaining microenvironments is (and always was) at hand.

Not only have conservators reached out to the facilities management staff for assistance in maintaining microclimates, but microclimate control system manufacturers have developed increasingly sophisticated control systems. Manufacturers are now including user-friendly control systems, and in some situations are supplying devices complete with output for connection to facilities management control systems.

With the addition of expertise in active microclimate control to their repertoire of heating, cooling, pollution control, and building management systems, facilities managers can now define and control their building's microclimates with more precision than ever before. In a number of institutions, the responsibility for maintaining microclimates in display cases is now the responsibility of their facilities management team. This is likely part of a natural progression that will follow to other institutions, both large and small, as active climate control system technology matures, and as more conservators turn to facilities staff to assist in the installation of these systems.

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