Relative Humidity and Temperature Guidelines:

By: Stefan Michalski
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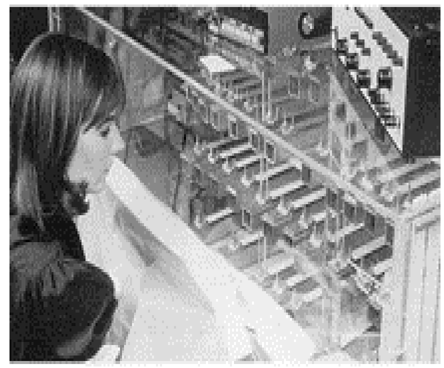
What's Happening?

There is a rumour going around that CCI no longer cares about temperature and humidity specifications! That there's no need to worry about those impossible standards! Well, the truth is that our approach has changed, but the issue has not gone away.

Conservation research scientists at CCI have shifted from defining a single, simplistic standard to identifying degrees of correctness or, more precisely, degrees of incorrectness. We try to estimate the benefit of basic control of the environment and the benefit of increasing sophistication. The following article summarizes CCI's current approach to temperature and relative humidity.



Testing the effects of changing RH on the behaviour of model canvas paintings and lining materials.

Temperature

Many artifacts will tolerate extreme cold (-30°C). Low winter temperatures indoors can reduce such problems as chemical self-destruction, pests, mould, energy consumption, and condensation in walls. At the other extreme, many artifacts will also tolerate brief excursions to 50°C. Aside from this general tolerance, three forms of incorrect temperature can be identified for a museum: temperatures that are too low, temperatures that are too high, and temperature fluctuations.

Temperatures that are too low are a problem for plastics and paints because these materials become brittle at low temperatures. Acrylic paints, for example, are quite leathery and robust at temperatures that are comfortable for humans, but turn glassy and increasingly brittle below 5°C. All paintings and coatings may crack at Canadian winter temperatures (below 5°C) either simply by contraction or by accidental blows to the paint.

Temperatures that are too high are incorrect for materials that self-destruct chemically within a human lifetime, such as acidic paper, nitrate and acetate films, celluloid, and rubber objects. The only practical solution for large quantities of these items is cold storage. Each 5°C drop will roughly double the lifetime of such materials, e.g., they will last a millennium at 0°C instead of a few decades at 25°C. Temperatures that are too high are also a problem for those artifacts that contain waxes or resins that soften above 30°C, such as lined paintings or artifacts that contain pitch.

Temperature fluctuations can be incorrect for artifacts that contain restrained brittle layers (e.g., enamels). Generally, however, temperature fluctuations by themselves rarely cause problems.

Relative Humidity

The single magic number of 50% RH which was advocated in the past, works for many artifacts but not for many others. The fluctuation specification of ±3% RH, although initially seen as simply cautious and conservative, turned out to be virtually impossible to achieve in the real world. Three decades of museum experience led to the same questions over and over again: Why these numbers? How important are deviations, given the difficulties involved?

In our experience, real examples of incorrect relative humidity in museums fall into one of four categories: damp, above or below a critical humidity, any humidity over 0%, and humidity fluctuations. Each incorrect RH applies to certain artifacts, and each causes very different rates of deterioration. Instead of stipulating one all-purpose and impossible "correct" humidity, CCI scientists outline the various incorrect humidities and emphasize the benefits of each level of control achieved. Overall, it is a return to the common-sense notion of avoiding extremes, augmented (rather than dominated) by scientific knowledge of more subtle effects.

Damp causes mould and rapid corrosion. Numerically, "damp" begins at 75% RH, but more important is the recognition that danger grows rapidly for every step beyond this point: 80% RH is much more incorrect than 75% RH, 85% RH is much more incorrect than 80% RH, and so on to 100% RH. For example, at room temperature, the time a museum can take to correct loss of control before mould appears on the most susceptible artifacts drops from about two months at 75% RH to about two days at 90% RH. Clearly, this influences not just building design but how museum staff must respond to humidity readings.

Relative humidities above or below a critical RH affects minerals that hydrate, dehydrate, or deliquesce at a particular RH. Besides natural history collections, this applies to contaminated metal objects (particularly marine or archaeological artifacts) and to some types of glass. Although damp may appear to be simply a type of "above a critical RH," in practical terms damp is so much faster and generic in its attack that it must be considered on its own. In contrast, susceptible minerals and contaminated metals are very specific in their critical RH values. Museum control depends on special data, special containers, and special rooms. In fact, this particular form of incorrect RH has been recognized and acted on for almost a century in archaeological metal collections.

Any RH above 0% is incorrect for artifacts that chemically self-destruct in a human lifetime via some process that requires moisture. The best known examples are acidic paper and acetate films. The data suggest that if the humidity were actually to reach 0% RH, then these processes would stop. However, maintaining RH below 5% year round is impractical. As shown in Table L temperature and humidity are linked on this issue. Although low temperature has the greater effect on an object's lifetime, low RH can be achieved more easily. Individual artifacts can be sealed in inexpensive containers with desiccant. On the scale of an entire building, low RH requires far less energy or building modification, and people can work in a building with low humidity more easily than in a budding with low temperature. Also, Canadian libraries and archives can achieve mass desiccation (as compared to mass deacidification) for free during the winter by using heating systems with no humidifiers.

Fluctuations in RH are incorrect for artifacts that contain restrained moisture-sensitive layers. This, of course, includes most of many museum collections. Certain artifacts, especially those that have recently been conserved, may also be very sensitive or vulnerable to RH fluctuations and may require special protection. Within the context of an overall preservation plan, however, it must be admitted that such damage can be repaired (at a cost), unlike the damage from such agents of deterioration as direct physical forces, fire, water, theft, pests, some contaminants, fading due to light, extreme damp, and chemical selfdestruction. Humidity fluctuations large enough to cause noticeable fractures in a single cycle can be considered "critical fluctuations". Fatigue mechanics shows that fluctuations that are below a critical level will only damage artifacts in very tiny increments. Keeping the straw off the camel's back has the most benefit!

In complex assemblies like furniture or paintings, each sub-assembly has its own critical fluctuation. Therefore, the issue becomes how to know all the critical values. The simplest approach is to review local history: What is the greatest fluctuation that lasted long enough for the whole collection to have responded? This is the collection's "proofed" fluctuation. In most Canadian museums, it is fair to estimate this as at least ±25% RH fluctuation from the local annual average. Thus, fluctuations smaller than this can only cause very slow cumulative damage. Another approach to determining critical fluctuations is to do analyses. Currently, research on paintings and wood suggest critical fluctuations for most artifacts begin at ±25% RH. Histories of artifact damage also suggest that fluctuations must reach beyond ±25% RH to cause sudden noticeable damage. History further demonstrates that many humidity-responsive assemblies tolerate extreme fluctuations of ±40% RH without noticeable damage if they are free to move.

Finally, no discussion of environmental control makes sense without reference to reliability. It is far more beneficial in the long run to build practical, fixable, forgiving systems that control the worst forms of incorrect humidity than it is to build elaborate building systems that control all forms of incorrect humidity for a few years and then fail (often creating worse conditions than those they replaced).

Conclusion

Has CCI radically changed environmental recommendations? No. A glance at Table I shows that institutions with the resources to give the best possible care to paint and wood have only a slightly wider permissible range of fluctuations (up to ±10% W than they did before. Fortunately, CCI's experience shows that this range is reasonable for good mechanical systems or for RH-controlled cases. The biggest change is the recognition that the large expenditures of resources necessary to achieve ±5% RH control as opposed to ±20% RH control bring modest benefits to humidity-related deterioration. These new environmental guidelines allow museums room for negotiating the difficulties of tight budgets, historic buildings, and essential humidity requirements.

Further Reading

Stefan Michalski, "Relative Humidity: A Discussion of Correct/Incorrect Values," *ICOM-CC 10th Meeting, Washington, D.C.*, (ICOM-CC: Paris, 1993), pp. 624-629.

Table 1
Effect of Incorrect RH and Incorrect Temperature on Museum Materials

	Stiff or brittle organic materials[a]	**Flexible organic materials, chemically stable**[b]	**Flexible organic materials, chemically self-destructing**[c]	**Inorganic materials**[d]
Damp(over 75% RH)	Mould. Softening of glue, some paint, wood. Canvas may shrink.	Mould. Sofeting of size, binders. Textiles may shrink.	Mould. Softening of size, binders.	Mould. Rapid corrosion of base metals.
Above or below a critical RH				For some: corrosion, crizzling, disintegration.
Above 0% RH			Disintegration and yellowing. If object life is 50y @ 50% then 100 y @ 30%, 200-400 y @ 10%.	
Fluctuation around a middle RH (stresses are zero)	Rate or risk of fracture growth: @±5%: P, V, A, W: none @±10%: P: tiny W, A: none-tiny @±20%: P:small W,A: tiny-small @±40%: P: severe W,A: small-severe	If brittle image layer, as P. If restrained by frame, ect., as W.	If brittle image layer, as P. If restrained by frame, ect., as W.	Fluctuations crossing a critical RH disintegrate some contaminated ceramics, stones, metal patina.
Temperature too high	Over 30°C, softening of some adhesives, waxes, pitch.	Over 30°C, softening of some adhesives, waxes, pitch.	Disintegration and yellowing. If object life is 50 y @ 20°C, then 200 y @ 10°C, 5000 y @ -15°C.	Some minerals disintegrate.
Temperature too low	Embrittlement, e.g., acrylics below 5°C.	Embrittlement.	Embrittlement.	
Temperature fluctuation	Rate or risk of fracture growth: @±10°C: P, V, A: none-tiny @±20°C: P, V, A: none-small @±40°C: P, V, A, W: none-severe Plus indirect effects if RH fluctuates.	If brittle image layer, as P. If restrained by frame, etc., as W.	If brittle image layer, as P. If restrained by frame, etc., as W.	Some composites (e.g., weak enamelling), as P.

a. For example, wood (W), oil and tempera paintings and polychrome (P), varnish (V), acrylic paintings (A).
b. For example, non-acidic paper and textiles, parchment, stable B & W photographs.
c. For example, acidic paper, acetate films, colour photographs.
d. For example, metals, minerals, ceramics, glass.