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Climate Control in Museums

This and the following three articles all address the subject of climate control guidelines in museums. These articles are drawn from different sources and were not written in response to each other. The first piece by David Erhardt, which was solicited by the Newsletter, was written as an overview of the CAL research and was never intended to address the issues criticized in the articles by Will Real and William Lull. Had publication deadlines allowed, Dr. Erhardt would have wished to clarify what he considers to be misunderstandings and misinterpretation of some of CAL's data in these articles. The second article is taken from the December 1994 issue of The Torch, a monthly publication for Smithsonian employees. It is not the press release referred to in the following two pieces (the press release is printed in full in the Abbey Newsletter, Aug.-Sept. 1994, v.18 #4-5), but contains substantially the same information. Finally, the last two articles, reprinted from the November 1994 Abbey Newsletter, were chosen because they provide opinions from two different segments of the conservation community.

This is, obviously, a subject of great concern to conservation and one about which thoughtful professionals have not reached a consensus. It is hoped that presentation of these articles will encourage constructive discussion.

The Determination of Allowable RH Fluctuations

David Erhardt, Marion F. Mecklenburg, Charles S. Tumosa, and Mark McCormick-Goodhart, Conservation Analytical Laboratory, Smithsonian Institution.

The most important factor in the preservation of collections is the maintenance of proper environmental conditions. Many environmental factors such as temperature, relative humidity (RH), light, pollution, and vibration affect the permanence of objects and materials. This article is an introduction to work that we have conducted relating to the determination of allowable fluctuations in RH.

Several considerations are involved in specifying RH for climate control. The first is the RH setpoint, the value that you are trying to maintain. The second is the allowable fluctuation, the short term variation that will be allowed. Third is the seasonal drift that will be allowed, the amount by which the setpoint is allowed to vary over the year. It is possible, if the allowable fluctuations are large enough, that seasonal drift might be accommodated within one overall allowable range.

A discussion of allowable humidity fluctuations should begin with a short summary of how the present guidelines developed. It has been known for a very long time that the extremes of RH cause damage. High RH results in mold growth and softening, while excursions to low RH can cause cracking and fracture sensitivity. Changes in RH were blamed for such environmentally induced damage as flaking paint, cracked wood, and glue failure. Reports of such damage increased as central heating became more widespread. Simple experiments in which some types of damage were duplicated by subjecting materials to large swings in RH showed that it was not just specific values of RH but changes in RH that could cause damage.

Anecdotal evidence indicated that damage could be prevented or minimized by maintaining a constant, moderate RH. The most famous example is that of the collections of the National Gallery, London. During World War II, the Gallery's collections were moved for safekeeping to mines in Wales. The climate in the caves was constant, although at too high an RH. The RH was adjusted by slightly heating the air to maintain between 55 and 60% RH, which earlier experiments had shown was the effective average in the then un-air conditioned Gallery. Within a matter of months, cracking, flaking, and other such problems that had occurred in the Gallery essentially disappeared. The problems returned when the collections were returned to the Gallery after the war. This experience was a prime justification for installing climate control soon after.

Obviously, much of the benefit of maintaining a constant, moderate RH derives from the avoidance of damaging extremes of RH. Benefit also was thought to derive from the avoidance of even small fluctuations, since large fluctuations were known to cause damage. Experiences such as that at the Gallery, combined with a lack of knowledge of whether small changes in RH caused damage, led to the present goal of maintaining a constant RH, or "flatlining". One value of RH was maintained year-round, with both rapid or daily changes (fluctuations) and seasonal changes (drift) reduced to the extent possible. Specifications often exceeded the ability of equipment or buildings to cope. This led to a number of problems. Overengineering of HVAC systems was common, often requiring major changes in the fabric of historic structures. Most older buildings, and surprisingly many new ones, are not capable of maintaining 50% or higher RH during very cold weather without condensation occurring in the building fabric. Maintaining one specific value of RH year-round can be much more expensive than allowing a seasonal drift, or bypassing RH control altogether when outside (intake) air is within a specified humidity range.

Practically, few institutions achieve the perceived "optimum" of absolutely constant RH. Most either allow seasonal drift or tolerate larger fluctuations than could be achieved with unlimited budgets. This is done, though, with a vague sense that the climate is not perfect, and that some tradeoff is being made in allowing some damage, How do we relate these tests, conducted at constant RH, with effects caused by changes in RH? The answer is illustrated in Figure 2, a detail of Figure 1. Assume the worst case, that a sample is fully restrained and not allowed to change dimension. If the RH is lowered from 48%, the sample tries to shrink, but cannot. Stress develops. This is equivalent to moving vertically, staying the same length but with increasing stress. If we reduce the RH to 23%, we end up at a point on the 23% RH stress-strain curve! This demonstrates a fundamental principle we have found to be true for all of the materials we have tested. Each point on the stress-strain curve corresponds to a unique RH. In other words, the path you take to a certain condition does not matter. Keeping the dimension constant and lowering the RH results in the same stress as allowing the sample to shrink freely as the RH is lowered, and then stretching it to the original length. This means that the effects of RH changes can be calculated from a series of stress-strain tests conducted at constant, but different, values of RH, rather than having to run much more time consuming tests involving fluctuating RH values. The only additional information required is the change in dimension caused by changes in RH. If we know the change in dimension caused by RH changes, and the amount a sample can be reversibly stretched, then we can calculate the allowable RH fluctuation.

Figure 3 is the moisture absorption isotherm for cottonwood, a plot of the change in length in the tangential dimension as a function of RH. The slope of this curve is therefore a measure of the sensitivity of dimension to changes in relative humidity. For a specific range of RH, the flatter the curve the smaller the response to changes in RH and the greater the change in RH required to cause damage. Figure 4 is a plot of the <u>slope</u> of the isotherm, the response to RH change. We see that the response to change in RH is least in the moderate RH range, and greatest at high and low RH. In the middle region, large changes in relative humidity must take place before dangerous stresses are possible. Thus, the allowable fluctuation in relative humidity is greatest in the 40-60% RH range, and least at the RH extremes. Changes in RH required to cause irreversible deformation, or ultimately failure, can be calculated for each RH.

This information is illustrated in Figure 5. This figure plots RH values which produce yield and failure as a function of the equilibrium, or stress-free, RH. These values assume full restraint. Starting at 50% RH, for example, one can reduce the RH to about 31% before yield, or irreversible deformation, starts to occur, and to about 13% before it breaks. Alternatively, the RH can be raised to about 68% before yielding in compression (compression set). The wood tries to expand, but is held "compressed" to its original length. Failure in compression is a more complex phenomenon than breaking in tension, and is not considered here. Thus, for cottonwood at equilibrium at 50% RH, the allowable RH fluctuation is <u>at least</u> ±18% RH. Remember, these calculations are for the worst case, tangential to the grain and assuming full restraint. An unrestrained sample can reversibly swell and shrink over much larger RH ranges.

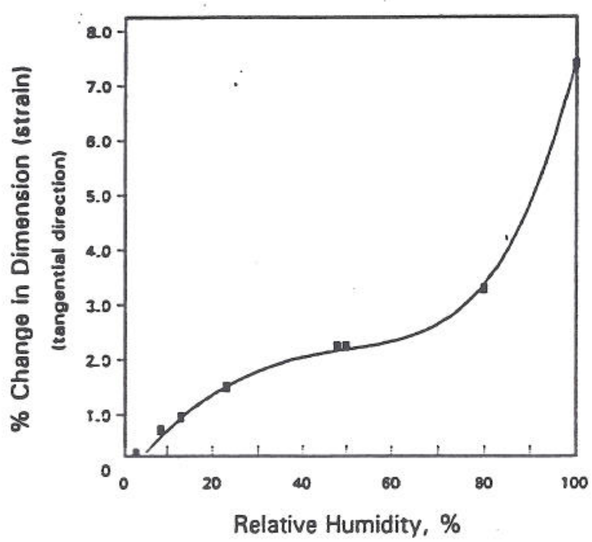

Figure 3. Moisture absorption isotherm for cottonwood. The change in dimension in the tangential direction is plotted as a function of RH.

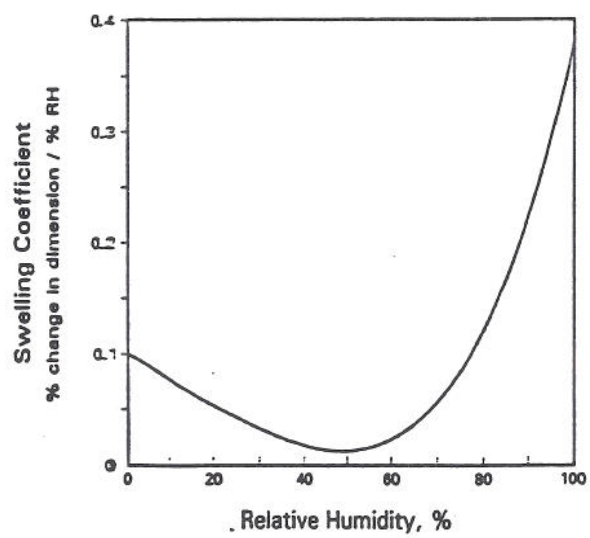

Figure 4. Swelling coefficient for cottonwood (tangential direction) as a function of RH. Cottonwood is relatively unresponsive to RH changes in the 40-60% RH range.

Note the very small allowable ranges at high and low RH. The dimensional response to RH changes increases at the extremes of RH, but the allowable reversible dimensional change does not. A restrained piece of cottonwood conditioned to outside conditions of over 70% RH cannot be brought into a museum at 50% RH without damage. This data also refutes the idea that high RH avoids mechanical damage because materials are softer and more flexible. Damage occurs, but in a different way. Materials are less likely to fracture, but permanent deformation does occur.

We have carried out such measurements and calculations for many other materials. Several points of interest emerge. The allowable fluctuation is a function of the relative humidity to which the object is equilibrated. The relative humidity with the maximum allowable fluctuation varies with the material. And, the allowable fluctuations can be quite different for different materials. An important point is that all of the allowable fluctuations are larger than those generally presently recommended, even though these values are <u>extremely</u> conservative. These values assume <u>full restraint</u> of the materials, long term exposure to the RH extremes, and produce changes that are well within the reversible, elastic range.

These values apply to individual materials. Because the allowable dimensional changes for most materials fall within the same range, the same limits also apply directly to composite objects. As long as you stay within the allowable range of the most sensitive material present, then <u>no</u> excessive strains will be produced in <u>any</u> material of the object.

Composite objects may, in fact, behave much like a single material. If all the materials have approximately the same dimensional response to RH changes, then the entire object swells and shrinks without producing significant stresses. The exception, of course, is massive objects in which the exterior responds to RH changes before the interior. In this case, the interior acts as an internal restraint, and the stresses and allowable fluctuations are as calculated for the restrained material. The <u>rate</u> of change of RH is not critical, as long as the maximum allowable strains are not exceeded.

A good example of a composite object is a painting on a wood panel. Figure 6 plots the RH sensitivity of the components of the layers of a typical panel painting. The values for cottonwood are plotted for the cross-grain direction only. Its response along the grain is so low as to be negligible. Because the wood panel is so thick relative to the other layers, its response determines the dimensional change (or lack of it) in the other layers. Cottonwood has an extremely small dimensional response to changes in RH along the grain, and essentially acts as a restraint. High RH produces compression in the upper layers in the grain direction as they try to expand, and low RH produces tension as they try to shrink. Across the grain, the situation is very different. In this direction, the RH sensitivity of the wood is about the same as the other materials at moderate RH. Changes in the middle RH range produce little stress, since all of the layers respond similarly. At high RH, however, the response of the

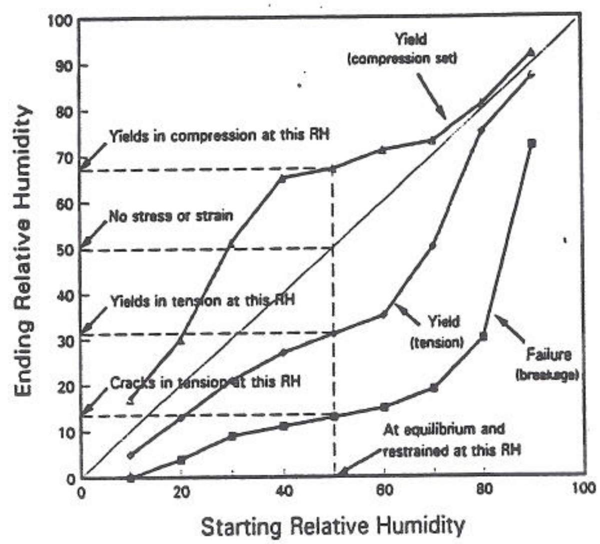

Figure 5. Plot of RH values which produce yielding or failure in restrained cottonwood (tangential direction) as a function of equilibrium RH value. A restrained, stress-free sample at 50% RH can be raised or lowered to 68 or 31% RH without permanent deformation. Failure occurs below 13% RH.

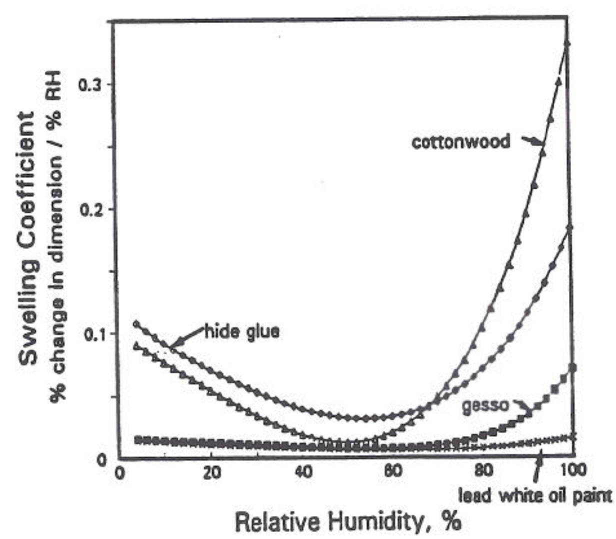

Figure 6. Swelling coefficients for typical layers of a panel painting as a function of RH. The layers respond similarly at moderate RH, but the wood (tangential direction) and glue layers shrink and expand much more than the gesso and paint layers at high and low RH. The wood has negligible response along the grain.

however small, to occur and accumulate. Many get by with outdated or inefficient equipment, waiting until they can afford to install and keep up a system capable of achieving environmental nirvana. Buffered display cases, microclimates, and other techniques are used extensively to improve upon ambient conditions thought to be less than optimal.

Obviously, things would be much simpler if the environmental requirements could be relaxed without causing damage. This requires answering two basic questions. First, do all RH fluctuations, no matter how small, cause damage, or is there a threshold of allowable RH fluctuation below which there is no damage? Second, if some fluctuation is allowable, how much? Additional questions can be asked, such as whether damage depends upon the rate of RH change, but research capable of answering the first two questions should provide most answers.

Our approach has been to determine the mechanism of damage caused by RH fluctuations, and the properties of materials involved in processes leading to damage. Many materials such as wood, glue, and paint absorb and desorb water and consequently change dimension as the relative humidity changes. If a material is unrestrained, this absorption and desorption is reversible within a reasonable range of relative humidity, and a material simply expands and contracts with changes in relative humidity. It is only when a material is restrained, either internally or externally, that this tendency to change dimension can cause stresses and resulting damage. If we lower the relative humidity, wood will try to shrink. If it is held in a rigid metal frame and prevented from shrinking, stresses develop. If these stresses are large enough, they result in permanent deformation or breakage. The question now becomes: Is there a range in which a material can be reversibly deformed, and how can one determine the relationship between RH and these stresses?

Figure 1 shows stress-strain curves for a piece of cottonwood at various relative humidities. These tests were conducted tangential to the grain, the weakest and most RH sensitive direction. Such data is typical for the many materials that we have tested. Applying a force (moving up the vertical axis) stretches the sample (moving to the right along the horizontal axis). Changes in dimension also can be produced simply by changing the RH with no force involved. This involves moving along the horizontal axis, which is why the stress-strain curves for different values of RH start at different positions along the horizontal axis. The curves are separated by the change in length due solely to changes in RH. The beginning of each curve is linear, and in fact <u>is reversible</u>. If we stay within the linear section of a curve, the wood resumes its original shape when the force is released. It is only when changes in length exceed certain values that the wood is irreversibly deformed (<u>yields</u>), or eventually breaks. The stress-strain curves allow us to determine how much a sample can be stretched <u>without</u> causing damage. For most materials, this value is about 0.3-0.4% of the original length.

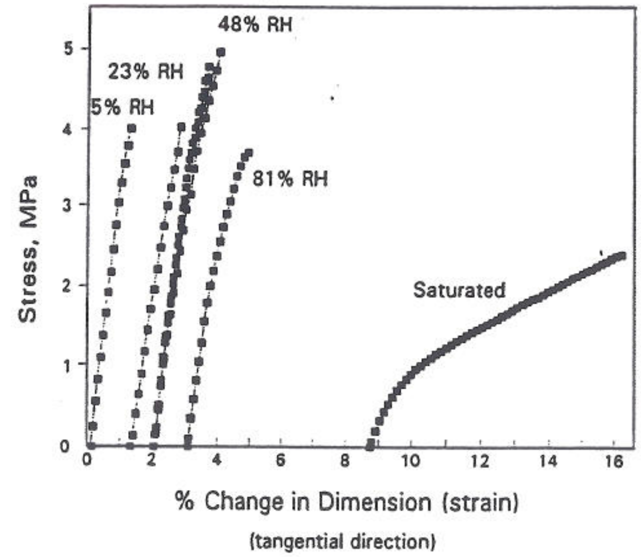

Figure 1. Stress-strain curves at various relative humidities for cottonwood in the tangential direction. The curves are displaced on the X axis by the change in dimension due solely to differences in RH.

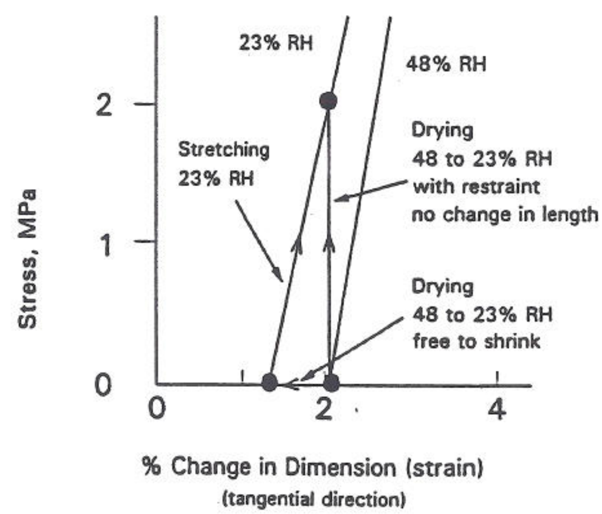

Figure 2. Detail of Figure 1. A sample of cottonwood held at constant length while the RH is lowered from 48 to 23% RH develops the same stress as a sample which is allowed to shrink while drying and then stretched to the original length.

wood increases dramatically, and the wood expands faster than the other layers. The wood can actually stretch the other layers at high RH! Similarly, at low RH, the greater shrinkage of the wood can result in compression of the gesso and paint layers. Stresses, strains, and resulting allowable RH fluctuations of composite objects all can be calculated directly from data such as that presented here.

Mechanical damage due to RH changes is not the only consideration in determining appropriate environmental conditions. We presently are in the process of similar research on the effects of temperature. Other factors, such as chemical reactivity, corrosion processes, hygroscopic salts, etc., also come into play. Such considerations were addressed in a paper presented at the recent IIC congress in Ottawa [1].

That most museum objects can tolerate, without mechanical damage, larger fluctuations than previously thought is not an excuse to abandon climate control. To the contrary, there always will be some materials and objects that require conditions different from or more tightly controlled than the main collection [1]. Standard approaches such as the use of microclimates and buffered cases are appropriate for such exceptions. If anything, the relaxation of allowable RH fluctuations for the general environment requires more thought and a better knowledge of the materials, history, and requirements of the collection.

This work is one result of a number of collaborative research projects related to environmental conditions in the museum that are being conducted by the authors at the Conservation Analytical Laboratory of the Smithsonian Institution. David Erhardt conducts research on the effects of environmental conditions on chemical degradation processes, Marion F. Mecklenburg specializes in structural mechanics, Charles S. Tumosa in materials properties, and Mark McCormick-Goodhart in environmental conditions for the storage of photographic materials. Questions or comments about our work can be directed to us at the following numbers and address:

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Reference

1. David Erhardt and Marion Mecklenburg, "Relative Humidity ~~Reconsidered~~ Reexamined", Preventive Conservation: Practice, Theory and Research, Preprints of the Contributions to the Ottawa Congress, 12-16 September 1994, The International Institute for Conservation of Historic and Artistic Works, pp. 32-38.

CAL scientists revise guidelines for museum climate control

By William Schultz, OPA Staff Writer

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For decades, museums have kept their thermostats at a steady 21 degrees Celsius (70 degrees Fahrenheit), with a relative humidity of 50 percent. Now, a team of Conservation Analytical Laboratory researchers has found that most museum objects can safely tolerate a wider range of both temperature and relative humidity.

In fact, according to the teams research, there can be as much as plus or minus 15 percent fluctuation in relative humidity and as much as 10C (50 F) difference in temperature. Within that range the scientists say, any object — whether it's Leonardo daVinci's painting "Mona Lisa" or an installation of Jeff Koons' vacuum cleaners — may be safely stored or placed on exhibit.

The researchers' insights could save museums, archives and libraries millions of dollars in construction and energy costs necessary to maintain rigid environmental controls.

The CAL researchers — Marion Mecklenburg, Charles Tumosa, David Erhardt, and Mark McCormick-Goodhart — reached their conclusions during a series of investigations of the chemical, physical, and mechanical properties of materials common to a wide variety of museum objects. The objects ranged from natural history specimens and archaeological artifacts, for example, to 19th century landscape paintings and photographic prints and film.

In the past year, the researchers have presented their work in a variety of papers and presentations for organizations such as the Materials Research Society, the American Chemical Society, and, most recently, at a meeting in Ottawa, Canada, of the International Institute for Conservation of Historic and Artistic Work.

"As scientists, we don't work from the idea that each object in a museum is unique," Mecklenburg says. "Rather, we start by looking at the whole picture — examining and understanding all of the materials found in the vast majority of museum objects."

Through informal discussions of their work, the researchers say, came the understanding that materials such as wood, cellulose, various polymer coating, fibers, minerals, pigments and the like share an overlapping range of tolerance to temperature and relative humidity.

"Up to 50 percent of construction costs for new museums and archival storage facilities may go toward highly overbuilt heating and cooling systems," Mecklenburg says. "Our research shows that such specialized systems are unnecessary. Most museums can adequately protect their collections with commercially available technology, such as the heating and cooling systems used in grocery or retail stores."

Moreover, Mecklenburg says, specialized heating and cooling systems that keep temperature and humidity stable can be expensive to operate. Seasonal variations in outdoor temperature and relative humidity, particularly in temperate climates, he says, can mean monthly energy costs that soar to tens of thousands of dollars in order to maintain strict environmental controls.

For older or historic buildings, Mecklenburg adds, making use of conventional equipment avoids the structural damage that might result from installing more elaborate heating and cooling systems.

The materials research at CAL that has let to the new insights about temperature and relative humidity involves laboratory tests of the properties (physical, mechanical, and chemical) of materials commonly found in museums. The overall goal of the CAL researchers is to apply the best scientific knowledge about various materials to the treatment and conservation of cultural, historic, artistic, and scientific artifacts.

Chemist Tumosa has measured the effects of changes in relative humidity on acrylic paints. For example, he has cooled and dried samples of acrylic paint on canvas to document responses to lowered temperature and humidity (if temperature and humidity are too low, many paints and coatings become brittle and crack). Tumosa also considers changes on stretched canvas in response to changing temperature and humidity, which might cause paint to crack and fall off.

Other materials — wood, photographic emulsions, paper — are subjected to high humidity, or they undergo accelerated aging through exposure to many potentially damaging environmental factors, including heat, humidity, light and various pollutants.

For example, McCormick-Goodhart has tested the effects of temperature and relative humidity on photographic prints and film, especially motion picture film. Results show that temperatures below freezing provide the best storage for maintaining the film (particularly color film) and that commercially available freezers are adequate, despite fluctuations in temperature that might occur with such off-the-shelf equipment. Precautions must be taken to guard film against high humidity, he says. For motion picture film, McCormick-Goodhart places each reel inside a zip-lock freezer bag, which is encased in a cardboard box.

In general, the CAL researchers say, for most materials the low end of the temperature / relative humidity range prevents biological damage from microbial growth and minimizes chemical reactions that occur naturally within objects over time. At slightly higher values for temperature and relative humidity, they say, physical damage is minimized.

"This work is capable of defining the tolerance limits for temperature and relative humidity of large classes of materials represented in museum collections," McCormick-Goodhart says. "It means we don't have to study every single object. That's the breakthrough."

Some Thoughts on the Recent CAL Press Release on Climate Control for Cultural Collections

by William A. Real
Carnegie Museum of Art, Pittsburgh

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While the research being conducted at the Conservation Analytical Lab (CAL) by Erhardt, Mecklenburg, et al., is extremely important to the conservation field, the conclusions drawn by the Smithsonian's press release ("Work of Smithsonian Scientists Revises Guidelines for Climate Control in Museums and Archives", August 21, 1994) appear to me to be premature. They could easily be misleading to museum administrators who are understandably eager to believe they can save vast sums of money with no ill effects to their collections. Indeed, as conservators, many of us have innumerable important projects we would like to see funded, and if there really is an imminent windfall here, we would all like to participate in it. Not to do so would be irresponsible.

To maintain the conditions described in the press release—35% to 65% relative humidity and 52 to 88 degrees Fahrenheit—museums in most climates will still need heating, ventilating, and air conditioning (HVAC) systems with humidification, dehumidification, reheat, boilers and chillers, fans, ducts, and controls (thermostats and humidistats); this basic equipment is required whether or not a stringent 50% ± 2% is maintained. It is true that to maintain very tight control, some museums have installed the most accurate humidistats available, which are indeed more costly than those required to maintain a wider fluctuation. Therefore, the research *does* seem to support the conclusion that some savings on humidistats are likely. However, even with expensive humidistats, the capital cost of HVAC in a recent museum renovation here in Pittsburgh (the Andy Warhol Museum) represented only about 20% of the total construction costs; the costlier humidistats were but a small fraction of that. The press release suggests that HVAC costs may run as high as 50% of construction costs.

Energy Costs and Maximum Safe Excursions

The researchers found that films of rabbit skin glue (a material very common in paintings, for example, and similar to materials present in many other types of cultural collections) can withstand fluctuations of ± 15% at a moderate relative humidity of 50% RH, but only ± 8% at the lower setpoint of 35% RH (Erhardt and Mecklenburg, "Relative Humidity Re-examined", in *Preventive Conservation: Practice, Theory and Research*, Preprints of the Contributions to the Ottawa Congress, 12-16 September, 1994. IIC, 1994). If museums adopt seasonally-adjusted RH setpoints, as the press release suggests, then collections are likely to be exposed to RH at the 35% setpoint for many months during the winter; to avoid damage, the tighter range of ± 8% must then apply. Therefore, reading between the lines of the research itself, I conclude that our HVAC systems must be designed to maintain RH control—at least for part of the year—at the tighter ± 8%, and not at ± 15%. A range of ± 8% is in fact not very much more than the ± 5% that many museums currently aim for as "standard".

If ± 8% is in fact our goal, as the research seems to support, albeit indirectly, then great savings are probably not to be had in energy costs, according to a computer-modelling study commissioned by the Getty Conservation Institute (Ayers, Lau, and Haiad, *Energy Conservation and Climate Control in Museums*. 1988, GCI). This research concludes that the difference in operating cost between maintaining RH at ± 2% vs. ± 7% is minimal, on the order of 3%. Of course, if the wider fluctuations are safe for our collections, we should take the savings, however minimal, and apply them to more fruitful causes.

The press release suggests that lower winter setpoints are not only just as safe for collections, but also safer for the buildings that house them. This depends, however, on the building. Some modern construction with no vapor barrier in the building envelope cannot even tolerate as much as 30% RH without substantial risk of condensation and damage to the building structure. As for new construction, the cost of installing vapor barriers is not particularly great, and if avoided, would not yield major savings. Of course, to retrofit an existing museum building with vapor barriers would indeed be very costly; some museums may in fact be able to avoid this step if the seasonally adjusted RH setpoints suggested by CAL are indeed safe for the collections. Unfortunately, the lower winter setpoints do not translate into savings on capital investment in HVAC equipment, because the same basic equipment is required to keep RH at 30% as to keep it at 50%.

Reliability of RH Measuring Instruments

At the recent IIC Congress, Jonathan P. Brown presented a paper entitled "Hygrometric Measurement in Museums: Calibration, Accuracy, and the Specification of Relative Humidity." The gist of the study was that RH measuring instruments, even when they are carefully calibrated (which is difficult and therefore rarely the case), are not necessarily giving us a realistic picture of our environments. This could be because an instrument is accurate in one RH range, but not in another, or because even if perfectly accurate, the instrument can only measure RH at one point in the building. Because of widely variable air flow, stratification, and microclimates, the RH measured at any given point may not represent the RH experienced by an object elsewhere in the same room. The author suggests that because of this, stringent RH specifications are irrelevant, because they cannot be reliably measured or confirmed.

My own conclusion from these facts is that we already have far less control over RH than we would like to believe. In spite of our attempts to maintain tight RH control, misguided or not, our collections are probably already experiencing conditions perhaps not unlike those now suggested in the press release, precisely because of the factors outlined in Brown's paper. If we begin to aim for wider fluctuations, our collections are likely to experience an even wider range of fluctuations than we intend, as they already do. Thus, we may believe we are specifying and maintaining an acceptably safe fluctuation, but in fact, at the object level, we may be exceeding the safe limit.

I would guess that conservators in institutions that strive for the best possible RH control still see, as I do, evidence of environmental damage. Try as we might, we seem unable to eliminate cracking, flaking, desiccation, and other signs of deterioration. Many of us try to further buffer our collections from the environment by means of microclimates or housings in an attempt to prevent damage, often with some success. I believe our collections present us with ample empirical evidence that attempting to minimize climatic damage is a worthy cause. It would be hard for me to ignore my experience and defer to the conclusions of the press release, which tell a much different story.

Susceptibility of Individual Items

Before a recent upgrade of our HVAC system, we had limited humidification capability (humidifiers were located in the central air handler only, rather than in the ducts serving each individual gallery zone, as they are now). As a result, winter RH levels frequently fell below 30%. On one of these occasions, a lacquer cabinet on loan from a major museum cracked and then tented and flaked out of control. Within a matter of hours, the object was so seriously damaged that it had to be removed from the exhibition and sent home.

An unwitting museum administrator, acting on the implications of the CAL press release, might make the mistake of compromising humidification and winding up with a system like the one we used to have, believing it to be perfectly adequate. Obviously, it would not be. It is important to note that nowhere does the research itself suggest that RH below 30% for this kind of material is safe. The press release does suggest, however, that equipment used for climate control in museums is probably excessive and unnecessary. It is this suggestion that lays the groundwork for unfortunate misinterpretations and omissions that could turn out to be unsafe for collections.

Furthermore, the lacquer cabinet incident is evidence that even among large classes of objects, there are indeed individual differences in response to RH; the cabinet was the only object, among many similar ones, damaged by the low RH episode. This experience leads me to question the conclusion offered in the press release that because "the [research] is capable of defining the tolerance limits of large classes of materials. . . we don't have to study every single object".

have and how their life under museum, library and archival care can be extended. However, the acceptable conclusions do not support the sweeping changes suggested in the press release. A reduced humidity set point in winter has been a viable, published and exercised option for decades. Where appropriate, it is common to consider and use this option for modern projects. Furthermore, acceptance of fluctuations has always been a practical necessity for many institutions. However, the broad relaxation of temperature and humidity criteria suggested in the press release is a policy not endorsed by most, including those who are familiar with the CAL research.

Building Systems and Costs

The sensational aspect of the press release is the reference to saving millions of dollars on building systems costs in museums. This estimate is not the result of research but is only speculation. My discussions with the CAL research staff indicate they do not have a broad knowledge of environmental control in buildings and HVAC systems; their observations are limited to their encounters with Smithsonian staff in regard to a few Smithsonian projects. No part of their formal research even touches on building systems. This does not mean that such research has not been done: it has been done to some extent by the Getty Conservation Institute. However, the CAL observations on building systems are apparently speculation from an inadequate information base.

The press release makes claims for annual operating cost savings using their "new" criteria. If they are suggesting that humidity levels should be allowed to fluctuate, as is suggested in the research they have presented at AIC, then this has already been simulated to some extent by research at the Getty (3). This showed that if humidity is allowed to vary by ±5% instead of ±2%, then annual HVAC operating costs would be reduced by just less than 2%; if allowed to vary by ±7% instead of ±2%, the savings would be just less than 3%. This is hardly a major change when HVAC energy costs may only be half of the total energy bill. Considering a museum's total annual energy costs, the savings at ±7% RH might come to just over 1% of the total. For all the museums in the United States, this might total as much as a million dollars, but only because of the number of museums involved. These same museums could realize greater savings from the use of tinted glazing or reduced lamp wattages while actually reducing environmental risk to the collection.

What *is* "Precision Heating and Cooling Equipment"?

The press release makes claims for construction cost savings. It perpetuates the myth that some sort of special, obscure, "precision" type of system is required for humidity control at 50% RH that is not required with relaxed criteria.

The press release states, "Up to 50 percent of construction costs for new museums and archival storage facilities may go toward highly specialized heating and cooling systems". The 50% is misleading; it is based on two Smithsonian projects. Neither is typical or representative of most museums and archives. For the vast majority of museum and archives projects, all mechanical and electrical systems in a new building account for about 30% of total project construction costs. The HVAC systems themselves account for only about 20% of total new construction costs, although they make up a higher percentage in renovations. Fifty percent is easily twice the typical fraction of the cost.

Good environmental control does not require special or extraordinary equipment: it consists mostly of avoiding common mistakes in equipment selection, location and installation. Except for unusual challenges that may be posed architecturally, an HVAC system for good humidity control around 70°F and 50% RH is quite simple: a modulating pressurized steam manifold humidifier; a cooling coil sufficiently cold to provide the needed dew point; a reheat coil; and a good control system. We regularly find these in buildings dating to the 1930s. What part can we delete, based on the CAL research? CAL scientists could not endorse 70% RH for the extended periods typical for systems without reheat or with a too-warm cooling coil. A humidifier is required to reach even 30% RH at comfortable working temperatures in temperate winters. At most one might downsize the steam boiler if 30% RH is the winter set point instead of 50% RH. The marginal cost in a slightly smaller boiler might be a few thousand dollars on a $5 to $10 million project.

The "remedy" to fluctuations is proper adjustment of controls and not the introduction of any expensive or complicated piece of equipment. Provided appropriate decisions are made, stable conditions for collections are neither unusual nor extremely expensive.

Compared to most other types of buildings, there are greater expenditures for museums and archives to provide the essential HVAC elements (humidifier, reheat, cold cooling coil). Most of the "extra" capital is spent in providing equipment that will work reliably for more than a year or two, and do so at reasonable cost. When construction cost cuts lead to the selection of short-life equipment, or equipment too expensive to operate, then the project is left without basic humidity control after only a few years.

The press release states that "making use of conventional equipment avoids the structural damage that might result from installing precision heating and cooling systems". This is inaccurate and misleading, and shows the poor quality of the information in the press release. "Conventional equipment" for humidification, by any sense of the words, will, if effective, pose a risk to a building envelope that is intolerant of humidified conditions in winter. The informed reader can likely determine that the press release is really trying to address the risk of condensation damage to intolerant buildings when a humidity level of 50% is maintained in winter. What they are trying to say is that reduced humidity in winter can be a valuable option to consider, but again, this is not new information.

HVAC Systems Protect Collections in Other Ways Too

The press release also omits a discussion of one of the more important aspects of HVAC: ventilation and filtration. There is a body of research demonstrating that air stagnation (which can lead to mold growth), dust, and certain pollutants are unquestionably damaging to many types of collections. If an institution opts to reduce these damaging factors, the resistance of filter sections at the targeted ventilation rates will probably dictate the requirements for fan sizes and the horsepower for fan motors. These are almost certainly more expensive than equipment needed for more routine application, but they have nothing to do with temperature and RH control. By focusing the HVAC question on climate control alone, the press release leaves the impression that the preservation benefits of filtration and ventilation are irrelevant.

In conclusion, there is no doubt that we as conservators and preservation managers must continue to learn from researchers, that we continually examine and when necessary revise our standards, and that we responsibly allocate limited resources where they most effectively benefit our collections. While the CAL research is a good example of how this process can work, the Smithsonian press release seems instead to undermine the validity of the research by drawing conclusions from it that are not supported by the facts. Perhaps the press release will turn out to be beneficial to the field insofar as it generates debate and encourages re-examination of the facts.

Further Comments on Climate Control Guidelines

by William P. Lull
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The following commentary is based on a letter that Mr. Lull sent in August to Museum News, *which had requested his thoughts on the CAL press release.*

I would like to offer the following facts and observations regarding the Smithsonian Conservation Analytical Laboratory (CAL) press release [reprinted in the August-September issue of the *Abbey Newsletter*]. Being neither a conservator nor a conservation scientist, I am reluctant to comment on the results of conservation research. However, when I saw the press release statements on safe environmental set points and museum buildings systems, I felt a response was necessary to help clarify some issues. After discussing this with many conservators, curators, conservation scientists and archivists over the past few days, I have also found a general interpretation of the press release not consistent with the CAL research I have seen presented.

In discussing the press release with Marion Mecklenburg, David Erhardt, and the CAL Director, Lambertus van Zelst, it is hard to draw the same sweeping conclusions that others drew from the press release. Their position on the press release issues I discussed with them is closer to that held by others in the conservation community. Dr. Mecklenburg noted that the "new" criteria should not be applied without the advice and possible moderation of conservation professionals.

The press release is misleading in two important respects. First, the description of the research conclusions does not accurately represent the generally accepted results of the research. Second, the observations on buildings systems are limited to the Smithsonian experience and not generally applicable to typical museums.

Mechanical vs. Chemical Degradation

From the two CAL papers I have seen presented at AIC, and from discussion with others, the emphasis of the CAL research highlighted in the press release is on how material samples mechanically tolerate temperature and humidity changes. The primary conclusion that might be drawn from their research is that test materials are not mechanically as sensitive to fluctuations in conditions as some believe. However, CAL's fluctuation research does not address the kinetics of the materials—how they deteriorate chemically over time with temperature and humidity conditions.

The press release implies, if it does not state directly, that prolonged conditions within the very broad range of conditions suggested (35%-65% RH, 52°-88° F) is safe. Paragraph 6 of the press release plainly states that objects "may be safely stored or placed on exhibit" under these conditions. This also implies that conditions may be maintained at the extremes of these ranges. Paragraph 14 apparently opens the door for any environmental conditions: the "low end" prevents some damage and "at higher values . . . physical damage is minimized". This is simply not the case for many if not most collections, and is not necessarily supported by the research. Field observations correlating object damage with humidity problems are overwhelming. Two papers that I coauthored and presented at AIC (1,2) document several such problems from unstable humidity.

While some materials in almost any collection can tolerate extremes, the conditions in a museum must be maintained for the most sensitive objects, unless they are housed under separate conditions. In fact, one CAL paper clearly notes that paper-based materials will have a dramatically longer life, three to five times as long, if the humidity is kept at an average of 30% rather than 50%, a far cry from conditions freely floating to highs of 65%. Moreover, research at the Library of Congress suggests that paper exposed to humidity cycling between 40% and 60% RH will deteriorate as if it were held constantly at the more damaging 60% level.

In summary, CAL research plays an important part as another piece in the puzzle of understanding how objects be-

Climate Control in Museums
Lull, continued

Museum, library and archives directors, as a rule, are neither scientists nor engineers. They are not equipped to deal with the details of research and building systems. They rely on others to interpret these issues. The press release suggests that capital and operating cost savings would accrue if things are changed according to their research. My main concern is that the press release will be used to relax environmental conditions in existing systems with good performance, and mandate unwise cost reductions for new or renovated systems. The well-meaning director, incapable of assessing the details but needing to conserve precious resources, might interpret the press release as cause to require a cut in capital costs for new building projects, to mandate a cut in operating costs for his current building systems, or to abandon important environmental improvement plans. These actions may be taken without regard for the actual environment that will result. Deletions consistent with the impression left from the press release, though not consistent with the CAL research, may result in collections being exposed to prolonged winter humidities below 25% RH, and prolonged summer humidities between 60% and 80%, conditions the CAL researchers would not endorse. Mechanical systems so compromised can require expensive retrofits to provide or restore essential elements (humidifiers, reheat, cold cooling coils) that cost less when installed initially.

References

1. "The Conservation Environment at the W.H. Mathers Museum: A Long-Term Path to Success", paper presented at the AIC annual meeting, 1990, by William P. Lull , Conservator, W.H. Mathers Museum.

2 "Humidity and the New Carriage Museum at the Museums at Stony Brook", paper presented at the AIC annual meeting, 1990, by William P. Lull; Merri Ferrell, Curator of Carriages, Museums at Stony Brook; and Linda E. Merk, Conservator at Fine Objects Conservation Inc.

3. "Energy Impact of Various Inside Air Temperatures and Humidities in a Museum when Located in Five U.S. Cities" ,ASHRAE Paper 3390, by J.M. Ayres, PE; H. Lau, Ph.D., PE; and J.C. Haiad, all with Ayres Ezer Lau, Inc., Los Angeles. *ASHRAE Transactions*, 1990, pt. 2; p. 100-111. (As an ASHRAE paper, it had to pass jury review before it was given.)

Part two of **An Introduction to Automatic Fire Sprinklers,** by Nick Artim will be printed in the May issue of the Newsletter. It was postponed in order to have room for the four preceding articles and the longer than usual Health and Safety, Technical Exchange, and Conference Review columns. For the same reason the Articles You May Have Missed items will be combined with next issues'.

Conference Reviews

Varnishes: Authenticity and Permanence

September 19-20, 1994, Ottawa

Part I

Perhaps the most significant event for painting conservators this year was the colloquium and workshop "Varnishes: Authenticity and Permanence", sponsored by the Canadian Conservation Institute (CCI) and Canadian Heritage. The colloquium was held on Monday and Tuesday (19-20 September 1994) and a workshop with limited enrollment was held Wednesday and Thursday. The colloquium was attended by 160 people from 17 countries from four continents.

The colloquium and workshop were organized by Dr. Leslie Carlyle and James Bourdeau. The original plan was for a small colloquium – something of a follow-up to the 1990 Brussels IIC conference. The goals of the conference were stated by Leslie Carlyle as being neither an attempt to reach a consensus nor to weigh in for or against any particular varnish, but rather a systematic examination of assumptions made about varnishes and varnishing.

The title of the colloquium "Varnishes: Authenticity and Permanence" was chosen with the following meanings in mind: authenticity connotes the appearance of varnish; and permanence, the stability of a varnish. Appropriately, the first talks were overviews of varnish research and the physical and chemical nature of varnish.

René de la Rie, Head of Scientific Research, National Gallery of Art, Washington, was the first presenter with a most appropriate **"An Overview of Research on Picture Varnishes"**.

René began his presentation with a slide of a 1754 painting showing a restorer in his studio removing a yellow varnish from a painting. René pointed out that of the traditional materials used by artists, natural resin varnishes are the most unstable. Fundamentally, natural resin varnishes are responsible for the varnish cycle.

A difficulty for researchers trying to investigate the varnish problem is that there is no objective measure for a good looking or good handling varnish. The components of that measure are chemical stability and the physical factors influencing the optical and handling properties of a varnish.

There are a number of ways to classify varnishes:(1) natural versus synthetic; (2) chemically: diterpenoid resins (sandarac, rosin); triterpenoid resins (gum mastic, dammar resin); or drying oil.; (3) by size: high molecular verses low molecular weight resins; or (4) by historical usage: the earliest varnishes were oil varnishes; spirit varnishes have been used since the 16th century; dammar began to be used in the 19th century; poly(vinyl acetates) date from the 1930's; poly(alkylmethacrylate)s,the1940's;and poly(cyclohexanone)s (ketone resins), from the late 1940's.

Some problems associated with early synthetic varnishes were the following: crosslinking (some acrylics); instability (ketone resins); and optical problems (polyvinyl acetates and acrylics). Another problem was the varnishing of paintings which were never intended to be varnished.