Resolving the Conflict between Building Preservation and the Proper Temperature and Relative Humidity Requirements of Collections

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“Essentially, relative humidity expresses the moisture content of air as a percent of what it can hold when the air is saturated.”
[at a given temperature]
“The standard specification of +/- 4 or 5% in RH control is based more on what we can reasonably expect the equipment to do than on any deep knowledge of the effect of small variations on the exhibit”.
Tulip Poplar, 48% RH 30 Second Inc. Test

Ultimate Strength

Modulus, E

Yield Point

Stress (MPa)

Strain mm/mm
The Mechanical and Dimensional Response of Cultural Materials to Moisture

- cellulose: wood, paper
- collagen: bone, ivory, glue
- artists’ paints: pigmented films
- minerals
- metals
- ceramics
Four basic organic structural compounds

Two sugars: chitin and cellulose
Two proteins: keratin and collagen
Cellulose
New Scotch Pine, The Three Primary Directions

Free Swelling Strains

Relative Humidity(%)
Scotch Pine, Tangential Direction

Measurement as per Wood Handbook
(.000441 / % RH)

Intermediate (30% to 65% RH) Measurement (.000267 / % RH)
Changes in dimension are diffusion controlled and are usually very slow for wood blocks or books.
Tensile Tests of Birch in the 3 Directions

Radial

Longitudinal

Tangential

Stress (MPa)

Strain (mm/mm)
Collagenous Materials

glues, gelatins, skins, parchments, leathers

Gelatins have been used extensively for centuries as glues. The gelatin is from rendered animal skins and bones. A particularly strong glue is from sturgeon swim bladders. Gelatins are found in furniture, sizes for canvas paintings, image emulsions for photographic prints and films. It is one of the strongest of the cultural materials.
It will take a 20% RH change to develop a mechanical strain of 0.004 when restrained. This is the smallest yield point.
The gelatins even when restrained can easily be cycled from 50% RH +/- 15% RH without damage.
20th Century Photographic Materials

The allowable environment for 20th century photographic materials. This includes the image emulsion layers, the paper and plastic substrates, and the dyes and silvers.
Artists’ Paints

This category can include oil paints, acrylic emulsion paints, alkyd paints, egg tempera, and others. Low temperature is a far greater problem than low relative humidity.
White Lead in Cold Pressed Linseed Oil

Relative Humidity (%) vs. Free Swelling Strains
Even with a desiccation from 60% RH to 30% RH, the change is only 0.005.
Naple's Yellow, Equil. Stress Strain Tests

- 48%RH, 23C
- 5%RH, -3C
- 5%RH, 23C

Relative Humidity Stresses
Thermal Stresses

Strain

Stress (MPa)
Glass Transition Temperature

- Acrylic paints +5°C
- Oil paints -10°C
- Alkyd paints -15°C
- Acrylic paints +5°C
Paints can sustain fairly large swings in relative humidity. Tests indicate that 40% RH +/- 15 can be tolerated easily. Low temperatures are a bigger threat to the stability of the paint films.
Computer Modeling of Canvas Supported Paintings

Models include all layers of the painting, linen fabric, glue size, oil ground and the oil design layers.
9 CYCLES

90% TO 35% RH
SIMULATED COOLING FROM 23 C TO -3 C AT 5% RH:
COMPUTER GENERATED STRESS DIRECTIONS
WITH SUPERIMPOSED CRACK PATTERN
Environmental Settings to Reduce Building Maintenance
Mold Growth

Effects of high relative humidity can be localized by lack of air circulation and/or by condensation.
Inappropriate relative humidity can cause salts to migrate to the surface of ceramics or to accelerate reactions at the surface of objects.
Metal corrosion from salt deposits reacting with ambient moisture
So..... What Is the Right Value?
Recommendations

An appropriate museum exhibition environment would be:

Winter; 40% RH +/- 5% RH
Summer; 55% RH +/- 5% RH
Temperature; basic visitor comfort
Fig. 1 ASHRAE Psychrometric Chart No. 1
FY 1993, Smithsonian Energy Costs

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Legend:
- **Green**: Electricity
- **Yellow**: Gas, Steam, Oil
New Smithsonian Environmental Guidelines

“For general collections and public spaces ....

70 +/- 4 degrees F and

Relative Humidity at 45 +/-8%.”

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