Storage Environments: The Big Picture
Image Permanence Institute
The Big Picture

• Define Types and Causes of Decay
• Managing a Preservation Environment
• Rhyme and Reason: The Research Behind It
• Sustainable Strategies
• The Future
Types of Decay

- Chemical
- Mechanical
- Biological
Causes of Decay

- Light
- Heat (T)
- Relative Humidity (RH)
- Environmental Pollutants
Storage Environment Focus

- Temperature (T)
- Relative Humidity (RH)
- Dew Point
Temperature

- **High T**
  - accelerates chemical deterioration
    - Rate of decay doubles every 5°C/9°F increase in T

**Why?**

- **Kinetics**
  - Energy of a gas particle is directly proportional to the temperature
Relative Humidity

Relative Humidity is the amount of water vapor in the air expressed as a percentage of the amount needed for saturation at the same temperature.
Dew Point

The temperature at which air containing a specific about of water becomes saturated. Dew Point determines the temperature and RH combination you can achieve.
Dew Point

Dew Point!
Dew Point Calculator

www.dpcalc.org
Water

Water is a beautiful thing, it is the source of all life.
Water

For your collection, water is the root of all evil
Water

A deeper look…

• As RH increases or decreases water diffuses into and out of the collection until it reaches equilibrium

What this means…

• Mechanical,
  – Objects physically expand and contract

• Chemical
  – Lots of water available for chemical reactions

• Biological
  – Mold city
The Face of Deterioration
Managing Preservation Environment

Cool T

Moderate RH

Moisture Content

Dew Point
Environmental Control

Static approach to environmental control
Environmental Control

Static approach to environmental control

[Graph of temperature and relative humidity from 2011-08-15 to 2012-09-23]
Fears

• **Extremes**
  – What are the upper and lower T and RH values?

• **Sudden changes**
  – Equipment failure
  – Power outage
  – Providing access

• **Slow changes**
  – Effects of seasonal changes over months
What is the big picture?

- Move Towards Sustainability
  - Maintain high preservation quality
  - Save energy
  - Save money
  - Reduce carbon footprint
What is the big picture?

- Maximize chemical stability
  - Cool/low temperature for organic materials
- Move from Static to Dynamic approach
  - Seasonal set points
  - Daily setbacks
  - Daily shutdowns
#1: Ideal T

First, address chemical stability. Keep T low

<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;20°C (68°F)</td>
<td>High Risk for Chemical Decay for Most Materials, Increase in Biological Activity in Damp Conditions</td>
</tr>
<tr>
<td>12-19°C (55-67°F)</td>
<td>Cool Temperatures Slow the Rate of Chemical Decay, Good for Most Materials Except Film and Color Photographs</td>
</tr>
<tr>
<td>5-12°C (40-54°F)</td>
<td>Beneficial for Film &amp; Photograph Collections, Good for Most Materials Except Paintings</td>
</tr>
<tr>
<td>&lt;0°C (32°F)</td>
<td>Best for film &amp; photograph collections, Required for degrading acetate &amp; nitrate film, Bad for CDs and DVDs</td>
</tr>
</tbody>
</table>
#2: Ideal RH

Second, avoid RH extremes for long periods of time (1-3 months). This can lead to mold and/or mechanical decay.

- **70% RH & Higher**
  - High Risk for Chemical, Mechanical and Biological Damage

- **65 to 70% RH**
  - 70% - High Risk for Mold Growth
  - 65% - Increased Risk of Chemical Decay and Mechanical Damage

- **55 to 65% RH**
  - 60% - High Risk for Mold Germination
  - 55% - Corrosion Risk

- **30 to 55% RH**
  - Generally Safe Zone for Most Materials

- **30% RH & Lower**
  - Low RH is beneficial for Chemical Decay BUT unsafe for most Organic Materials
  - Low RH is Safe for most Inorganic Materials (Metals)

**Safe Zone**
Some Facts

• Thermal equilibration is fast
• Moisture equilibration is slow
• Ambient RH will have impact over a long period of time
• Enclosures help buffer changes
• T, RH, Dew Point, and collection materials have a dynamic relationship
Experimental Profile

Profile: Weekly Cycle at Constant Dew Point
Extreme scenario—sudden T and RH change
Enclosures

Metal edge cardboard box  
Museum case  
Portfolio box
Thermal Equilibration

Fast!

<table>
<thead>
<tr>
<th>Materials</th>
<th>Configuration</th>
<th>Time for 90% E</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 x 5-in. sheet film</td>
<td>Stack of 500 sheets in metal drawer</td>
<td>6.25 hours</td>
</tr>
<tr>
<td>3.5 x 5-in. RC prints</td>
<td>1,000 prints in cardboard box</td>
<td>4 hours</td>
</tr>
</tbody>
</table>
# Moisture Equilibration

## Slow!

<table>
<thead>
<tr>
<th>Materials</th>
<th>Enclosures</th>
<th>90% Equilibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardcover Book</td>
<td>Book on shelf</td>
<td>One month</td>
</tr>
<tr>
<td>35mm film</td>
<td>Metal can</td>
<td>Six months</td>
</tr>
</tbody>
</table>

Moisture Equilibration at 20°C (68°F)
T Equilibration

Ambient vs. Core
Experiment Reminder
RH Equilibration

Changes in Microenvironments: matted photographs in a cardboard box
RH Equilibration

Changes in Microenvironments: cardboard box and museum case

Ambient vs. inside enclosures
Don’t Sweat the Small Stuff

Conclusions: short term fluctuations are not fully experienced by the collection objects

Profile: gradual changes over 8 hours

Ambient vs Core of Book
T + RH + Collection = Dynamic Relationship

• Potential for self-buffering effect
• If there is enough hygroscopic material in a closed space, the material is capable of stabilizing RH fluctuations otherwise caused by T cycling.
  – Small quantities of moisture desorbed or adsorbed by collection materials responding to T cycling contribute to maintaining a steady ambient RH
Relationship: T, RH, Dew Point

This phenomenon occurs primarily in an empty room.
Relationship: T, RH, Collection

Empty, sealed space
T change only
Relationship: T, RH, Collection

Full Space

The image shows a graph plotting temperature (T) and relative humidity (RH) over a period from 2011-01-25 to 2011-03-10. The graph indicates fluctuations in temperature and humidity, with a clear annotation pointing to specific data points.
Sustainable Strategies

• **Shutdowns**
  – Shutting down HVAC over night and weekends

• **Setbacks**
  – Adjusting set points nights and weekends

• **Seasonal set points**
  – Cooler and drier in the winter, warmer and more humid in the summer
  – Stay within “Safe Limits”
## Daily Shutdown

### Night and weekend shut down of HVAC

<table>
<thead>
<tr>
<th>Zone</th>
<th>Shutdown Schedule</th>
<th>HVAC Operation Weekdays</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Shutdown during 6 hours</td>
<td>Cool to 30°C&lt;br&gt;Heat to 13°C</td>
</tr>
<tr>
<td>B</td>
<td>No Shutdown.</td>
<td>21°C</td>
</tr>
<tr>
<td>C</td>
<td>Shutdown during 8 hours</td>
<td>Cool to 30°C&lt;br&gt;Heat to 13°C</td>
</tr>
<tr>
<td>D</td>
<td>Shutdown during 8 hours</td>
<td>Cool to 32°C&lt;br&gt;Heat to 10°C</td>
</tr>
<tr>
<td>E</td>
<td>Continuous Temp. and RH control</td>
<td></td>
</tr>
</tbody>
</table>
Daily Shutdown: T Control Only

Ambient environment: no setback (B) and 8 hour setback (D)
Moisture Equilibration is Slow

Despite the fact RH equilibrium is slow, it is the seasonal RH changes that are most prevalent.
Enclosures Matter

Stepped RH profile at 20°C on RH level at the core of matted photographs in different enclosure types

B: cardboard box; C: portfolio box; D: museum case
Case Study: Setbacks and Shutdowns

One Year
Case Study: Setbacks and Shutdowns

One Day
Further Research

• What about that moisture gradient, aka the “skin”?
• What about that self-buffering phenomenon?
• What if I don’t have RH control?
Stepped RH profile at 20°C on RH level in the microenvironment of matted photographs in different enclosure types
C: portfolio box; D: museum case
Mechanical Deformation: Digital Image Correlation (DIC)

- Complex, composite objects
- Variety of materials
- Different hygroexpansivities
  - Absorbs moisture and expands as RH increases
“Skin” of the Book

60%-25%-60% RH
DIC

Experimental Set up

2D Model of Parchment

Random Speckle Pattern
Mechanical Deformation

Parchment V6, mean secondary strain
- V6 30% mean(e2)
- V6 20% mean(e2)
- V6.2 10% mean(e2)

Parchment Samples
Profile: 50-30-50 %RH
DIC

Preliminary DIC study vellum bound book
Buffering & T control

- Manage moisture content through temperature adjustments
- Determine how much is too much moisture
- Continue self-buffering
Conclusions

- Short term fluctuations are not fully experienced by the collection objects
  - Shutdowns and Setbacks can save money and will do no harm to your collection collection
  - Stepped seasonal RH profile may delay moisture equilibration of materials
- Enclosures help
  - Consider time, space money
- Self-buffering effect
  - Collection helps to buffer RH fluctuations and can minimize moisture content changes at the center of the object
Thank You

National Endowment for the Humanities
Division of Preservation and Access