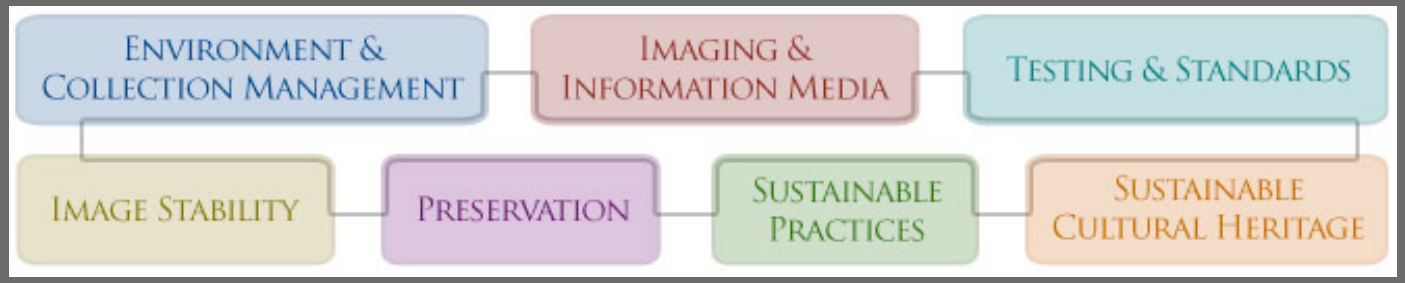
Storage Environments: The Big Picture

Image Permanence Institute
December 2017

IPI IMAGE PERMANENCE INSTITUTE

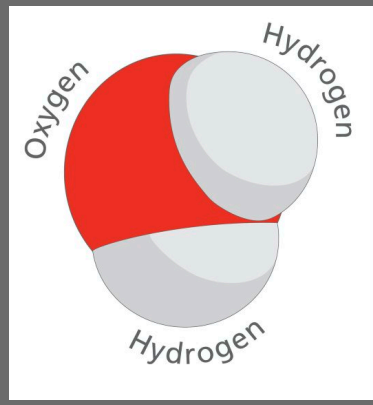
Image Permanence Institute

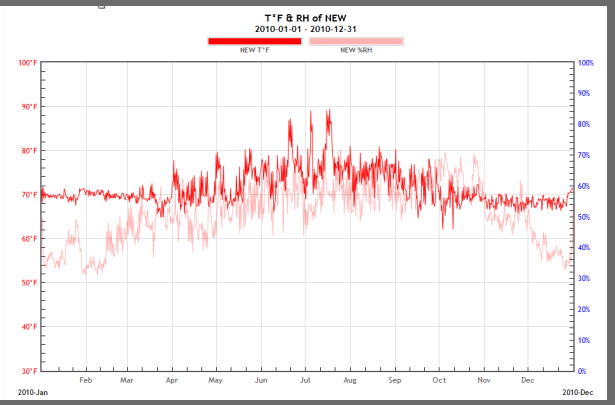


IPI IMAGE PERMANENCE INSTITUTE

The Big Picture

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

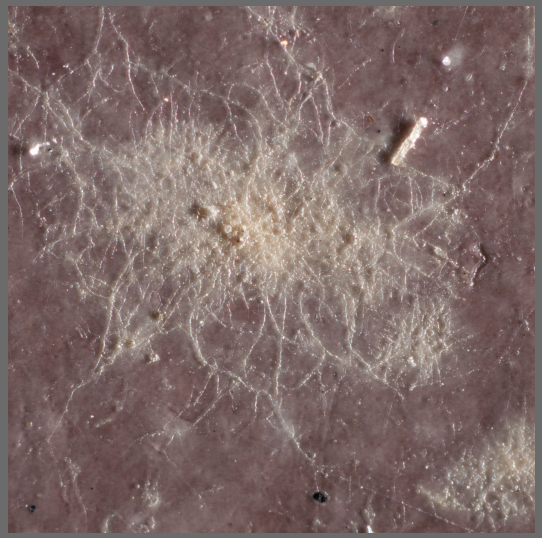




IPI IMAGE PERMANENCE INSTITUTE

Types of Decay

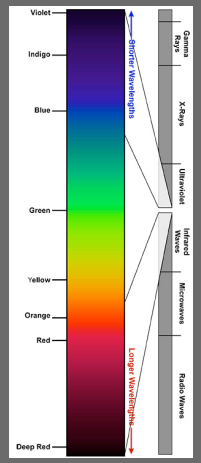
- Chemical
- Mechanical
- Biological

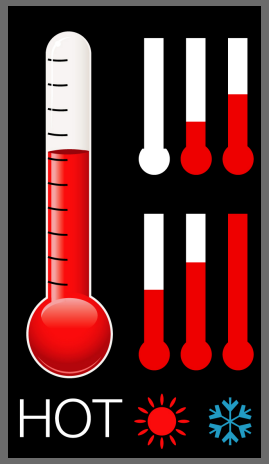


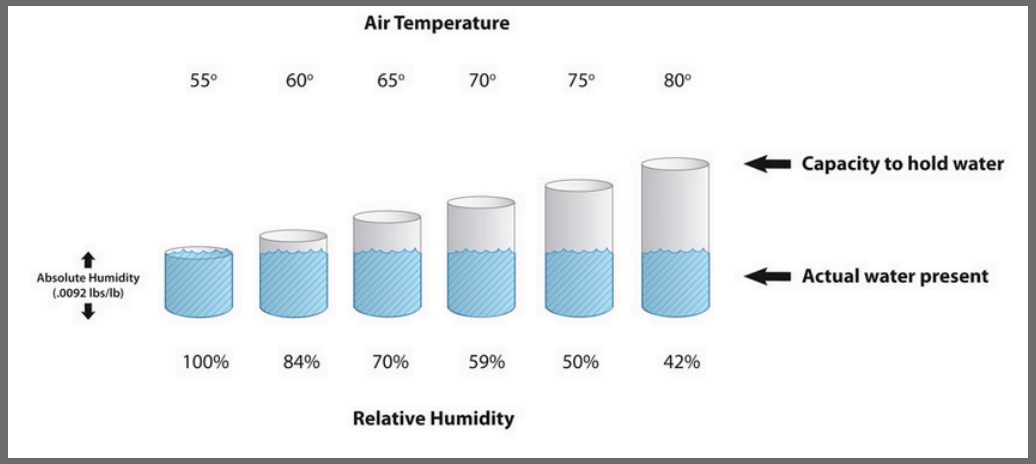
IPI IMAGE PERMANENCE INSTITUTE

Causes of Decay

- Light
- Heat (T)
- Relative Humidity (RH)
- Environmental Pollutants



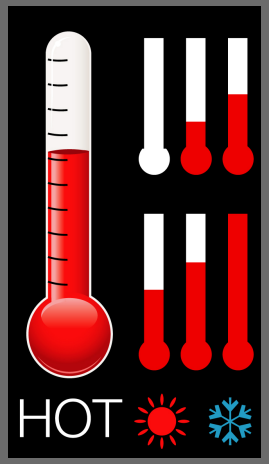


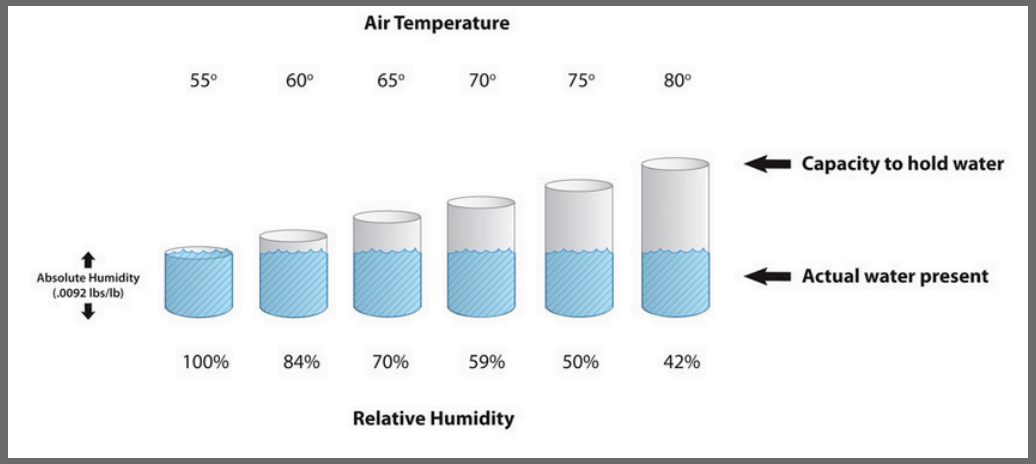


IPI IMAGE PERMANENCE INSTITUTE

Storage Environment Focus

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





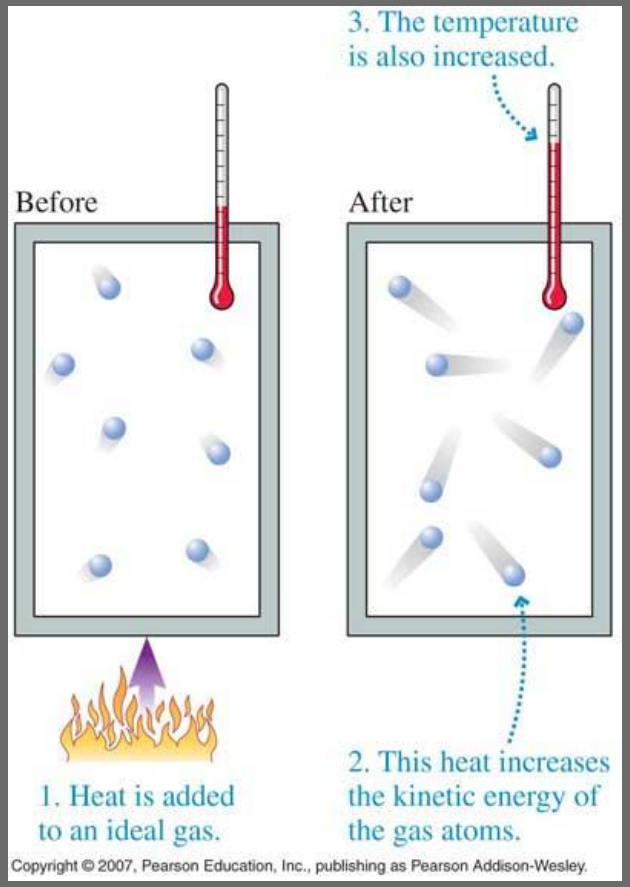
IPI IMAGE PERMANENCE INSTITUTE

Temperature

- High T
  - accelerates chemical deterioration
    - Rate of decay doubles every 5ºC/9ºF increase in T

Why?

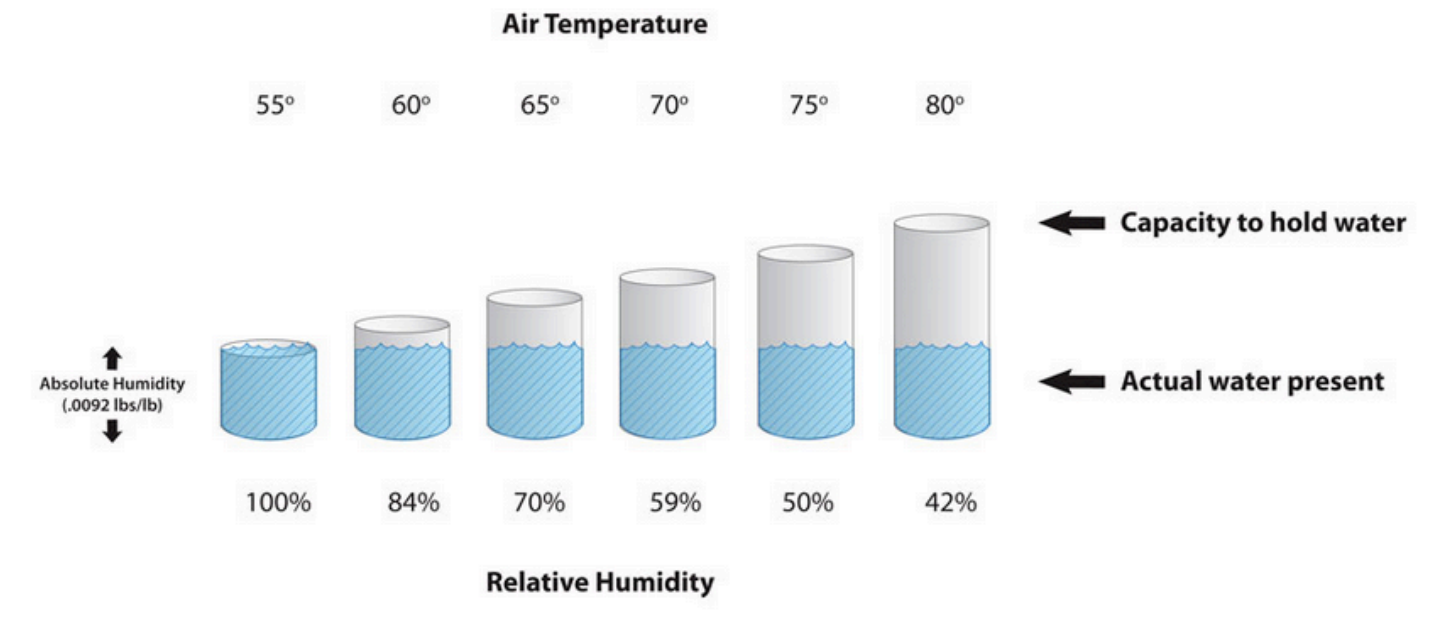
- Kinetics
  - Energy of a gas particle is directly proportional to the temperature



IPI IMAGE PERMANENCE INSTITUTE

Relative Humidity

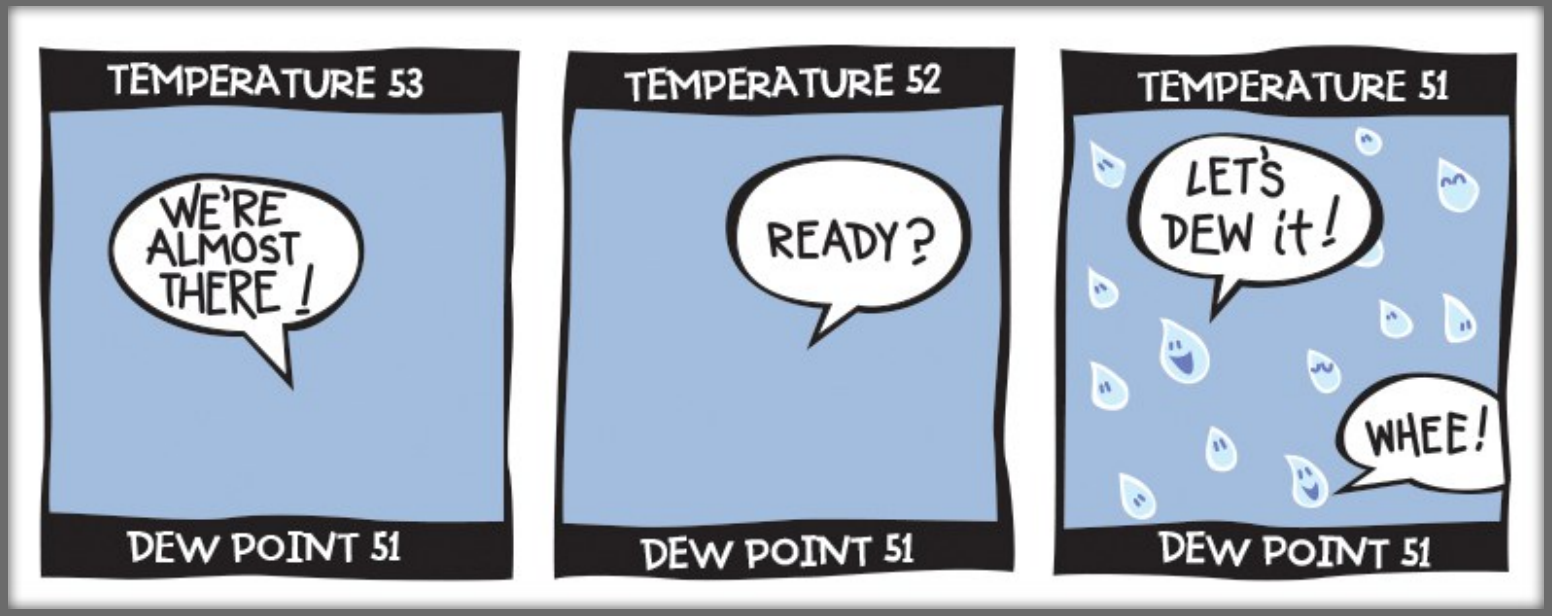
Relative Humidity is the amount of water vapor in the air expressed as a percentage of the amount needed for saturation at the same temperature.



IPI IMAGE PERMANENCE INSTITUTE

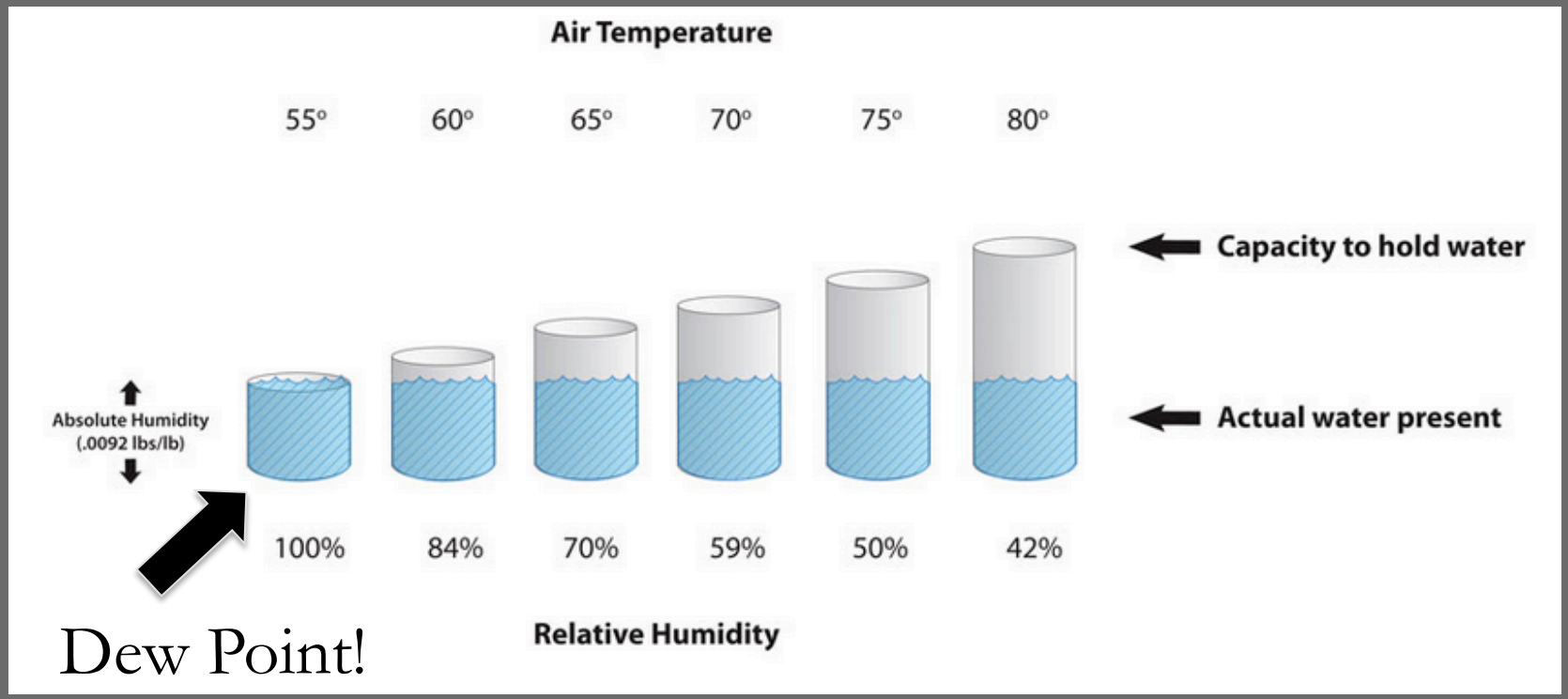
Dew Point

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



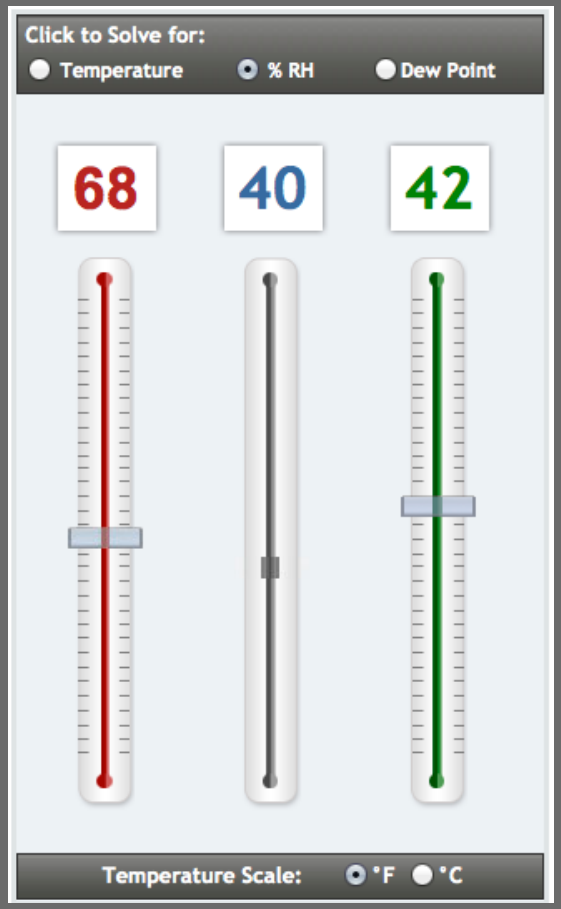
IPI IMAGE PERMANENCE INSTITUTE

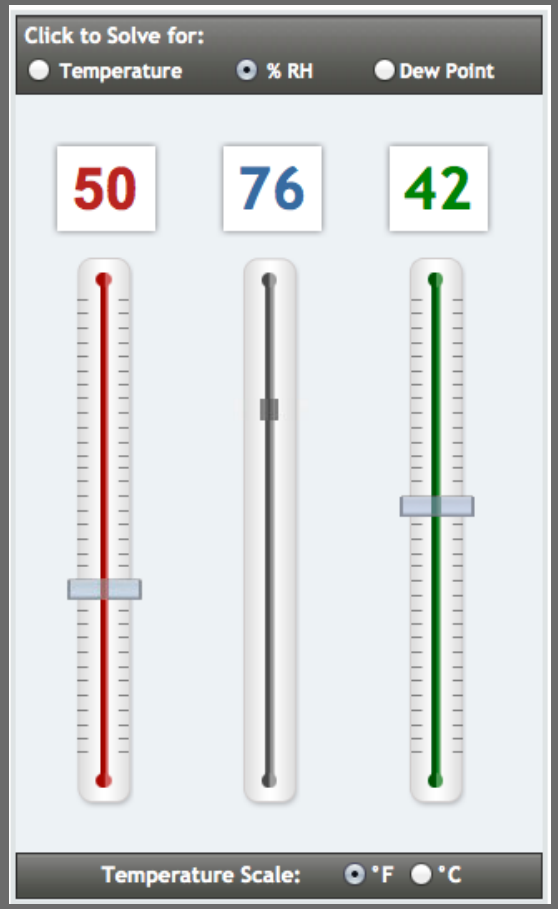
Dew Point



IPI IMAGE PERMANENCE INSTITUTE

Dew Point





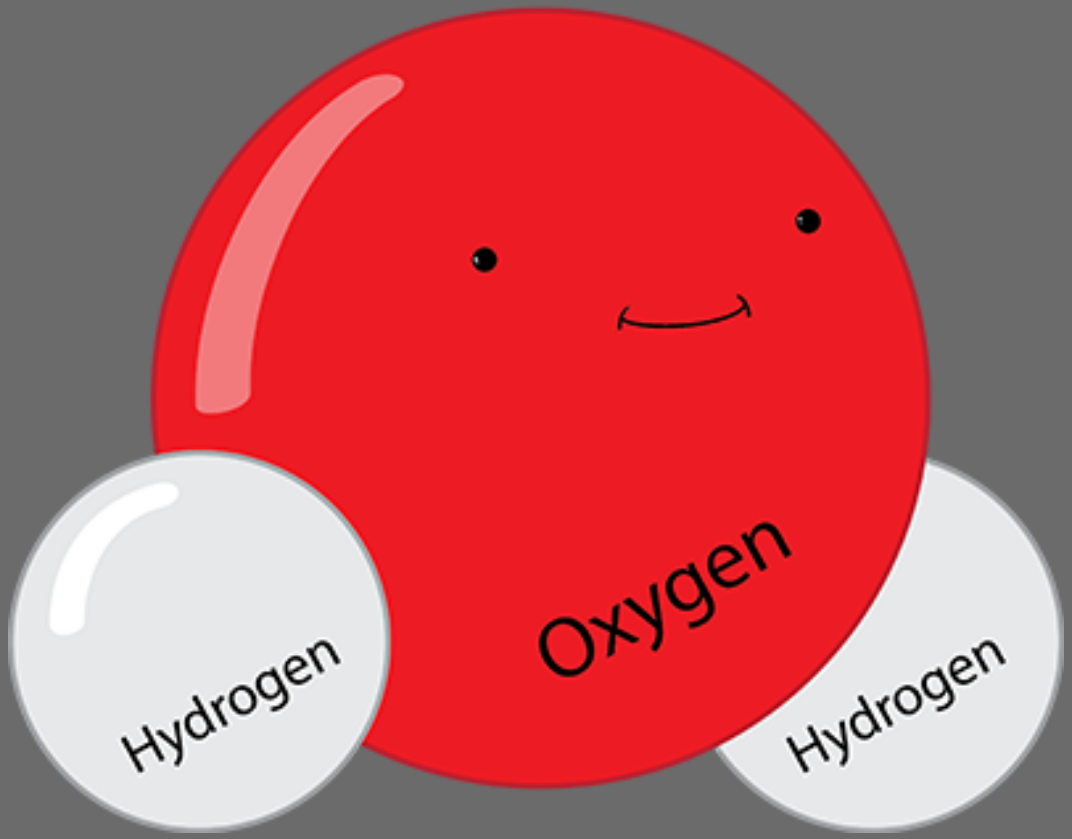
Dew Point Calculator

www.dpcalc.org

IPI IMAGE PERMANENCE INSTITUTE

Water

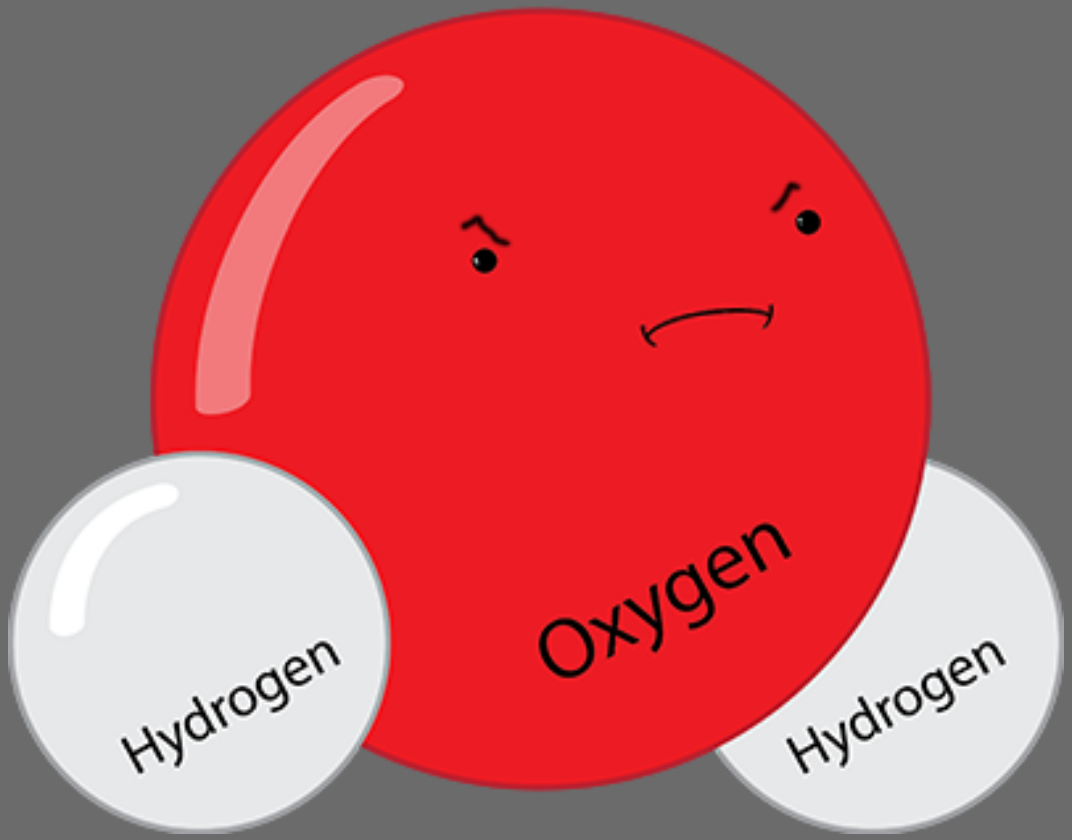
Water is a beautiful thing, it is the source of all life



IPI IMAGE PERMANENCE INSTITUTE

Water

For your collection, water is the root of all evil



IPI IMAGE PERMANENCE INSTITUTE

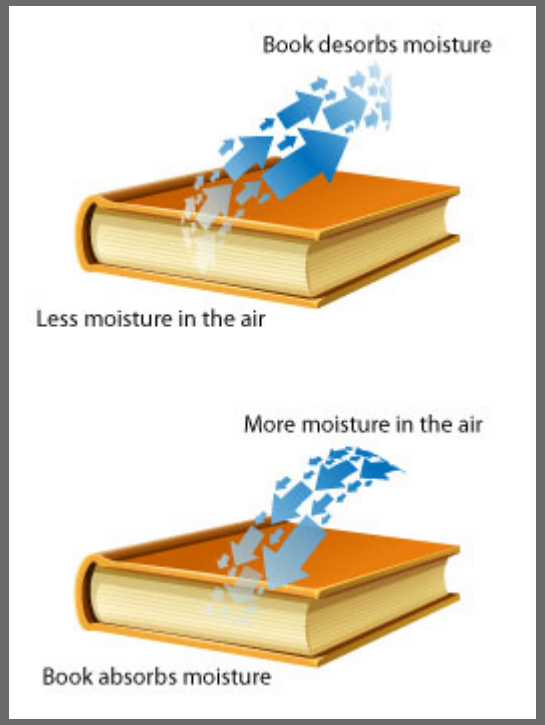
Water

A deeper look…

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

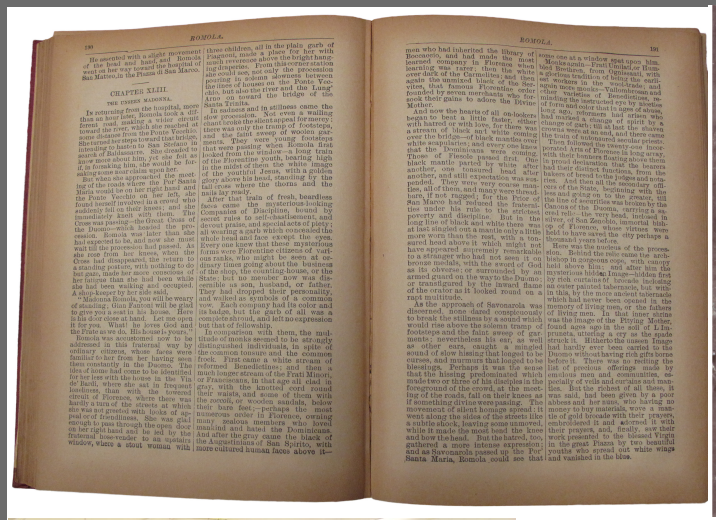
What this means…

- Mechanical,
  - Objects physically expand and contract
- Chemical
  - Lots of water available for chemical reactions
- Biological
  - Mold city



IPI IMAGE PERMANENCE INSTITUTE

The Face of Deterioration



ROMOLA.

He answered with a slight movement of his hand and hand, and Romola went on her way toward the hospital of San Matteo, in the Piazza di San Marco.

CHAPTER XLIII.

THE FAMISH MADONNA.

In returning from the hospital, more than an hour later, Romola took a different road, making a wider circuit toward the river, which she reached at some distance up the Ponte Vecchio. She turned her steps toward that bridge, in order to hasten to San Stefano in search of Baldassarre, to have decided to know more about him; yet she felt as if in forsaking him, she would be asking some new claim upon him.

But when she approached the middle of the roads where the Pur Santa Maria stood, with her right hand and the Pitti Vecchio on her left, she found herself involved in a crowd who suddenly fell on their knees, and she immediately knelt with them. The Cross was passing—the Great Cross of the Duomo—which healed the pestilence. Romola was later than she had expected to be, and now she must wait till the procession had passed. As she rose from the ground, when the Cross had been passed, the return to a kneeling posture, with nothing to do but gaze, made her more conscious of her fatigue than she had been while she had been walking and occupied. A shop-keeper by her side said,

"Madonna Romola, you will be weary of standing; this Fattori will be glad to give you a seat in his house. Here is his door close at hand. Let me speak it for you. What! he loves God and the Frate as we do. His house is yours."

Romola was accustomed now to be addressed in this friendly way by ordinary citizens, whose faces were familiar to her from the long days spent constantly in the Duomo. The idea of home had come to be identified for her less with the house in the Via de' Bardi, where she sat in frequent loneliness, than with the towered circuit of Florence, where there was hardly a turn of the streets at which she was not greeted with looks of appeal or of friendliness. She was glad enough to pass through the open door on her right hand and be led by the fraternal lose-vender to an upstairs window, where a stout woman with three children, all in the plain garb of Fiesole, made a place for her beside Fiagnoni, which reverence above the bright hangings draperies. From this elevation she could see, not only the procession of the Cross, but also the river and the Lungo' Arno on toward the bridge of the Santa Trinita.

In silence and in stillness came the slow procession. Not even a wailing for mercy; there was only the tramp of footsteps, and a faint sweep of woolen garments. Deer were young footsteps were passing when Romola first looked from the window—a long train of the Florentine youth, bearing high in the midst of them the white image of the youthful Jesus, with a golden glory above his head, standing by the fall cross where the thorns and the nails lay ready.

After that train of fresh, beardless faces came a train of mysterious-looking Companies of Discipline, bound by secret vows to self-chastisement, and secret praise, and special acts of piety; all wearing a garb which concealed the whole head and face except the eyes. Every one knew that these mysterious forms were Florentine citizens of various ranks, who might be seen at ordinary times going about the business of the shop, the counting-house, or the State; but no member now was discernible as son, husband, or father. They had dropped their personality, and walked as symbols of a common vow. Each company had its color and its badge, but the garb of all was a complete disguise, and left no expression but that of fellowship.

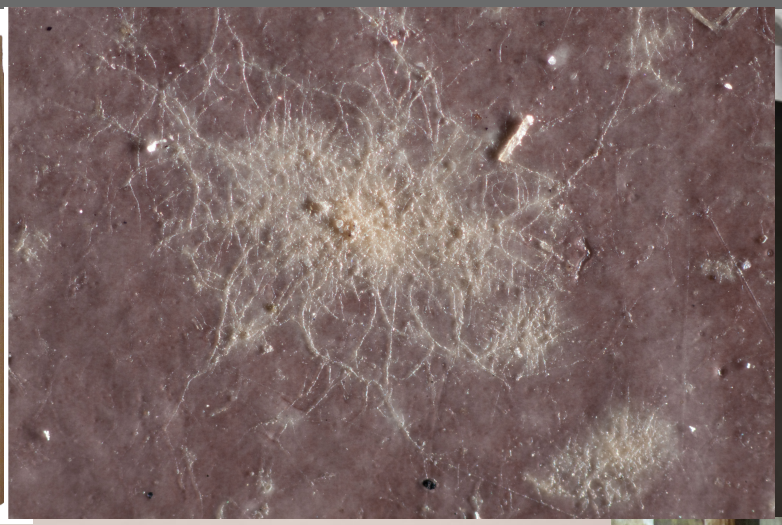
In comparison with them, the multitude of monks seemed to be strongly distinguished individuals, in spite of the common tonsure and the common frock. First came a white stream of reformed Benedictines; and then a much longer stream of the Frati Minori, or Franciscans, in that age all clad in gray, with the knotted cord round their waists, and some of them with their sandals, or wooden sandals, below their bare feet,—perhaps the most numerous order in Florence, owning many zealous members who loved mankind, and hated the Dominicans. And after the gray came the black of the Augustinians of San Spirito, with more cultured human faces above it—

ROMOLA. 191

men who had inherited the library of Boccaccio, and had made the most learned company in Florence when learning was rare; then the white, over dark of the Carmelites, and lastly the unmixed black of the Servites, that famous Florentine order which had been overbasmy who forgook their gains to adore the Divine Mother.

And now the hearts of all on-lookers began to beat a little faster, with hatred or with love, for there came a stream of black and white coming over the bridge—of black mantles over white scapularies; and every one knew that the Dominicans were coming. Those of Fiesole passed first. One black cloak patched by white after another, some tonsured head after another, and a long, long stream was succeeded. They were very coarse mantles, all of them, and many were patched, if not ragged; for the Prior of San Marco had reduced the rule of his order under his rule to the extremest poverty and discipline. But in the long line of black and white there was at last singled out a mantle only a little more worn than the rest, with a tonsured head above it which might not have appeared supremely remarkable to a stranger who had not seen it on bronze medals, with the sword of God as its obverse; or surrounded by an armed guard on the way to the Duomo; or transfigured by the inward flame of the orator as it looked round on a rapt multitude.

As the approach of Savonarola was discerned, none dared conspicuously to break the stillness by a sound which would rise above the solemn tramp of footsteps and the faint sweep of garments; nevertheless his ear, as well as other ears, caught a mingled sound of slow hissing that longed to be curses, and murmurs that longed to be blessings. Perhaps it was the sense that the hissing predominated which made two or three of his disciples in the foreground of the crowd, at the meeting of the roads, fall on their knees as if something divine were passing. The movement of silent homage spread: it went along the sides of the streets like a subtle shock, leaving some unmoved, while it made the most bend the knee and bow the head. But the hatred, too, gathered a more intense expression and as Savonarola passed up the Pur' Santa Maria, Romola could see that



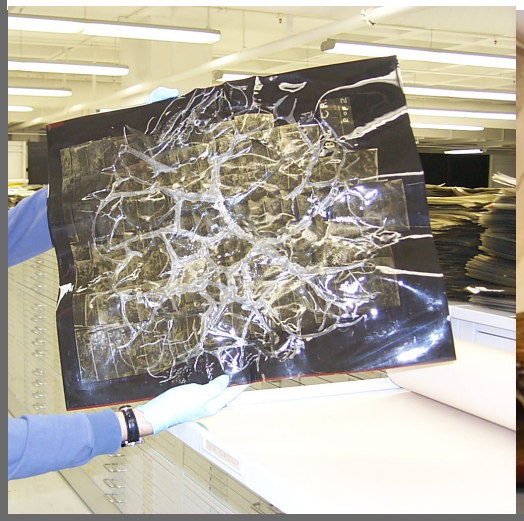
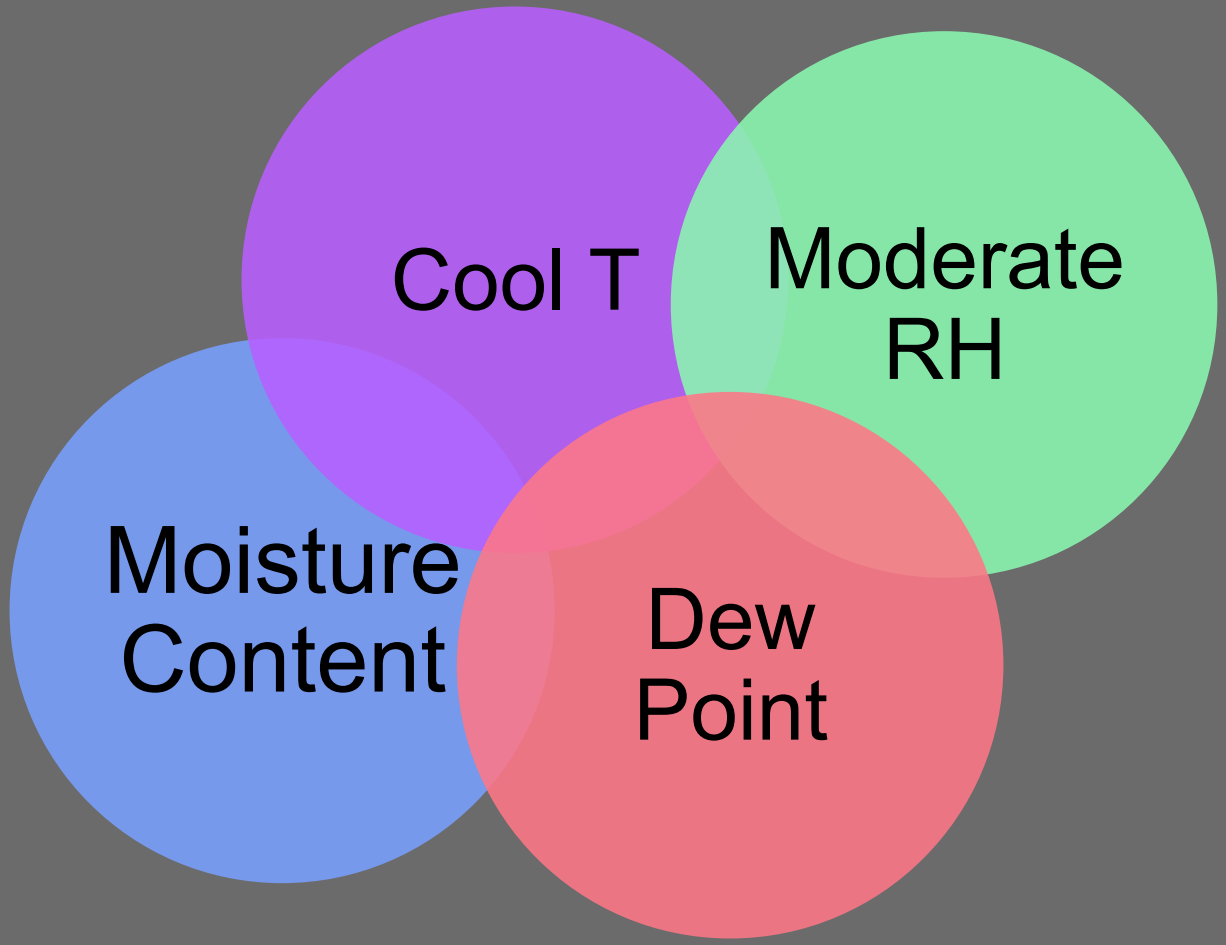


IMAGE PERMANENCE INSTITUTE

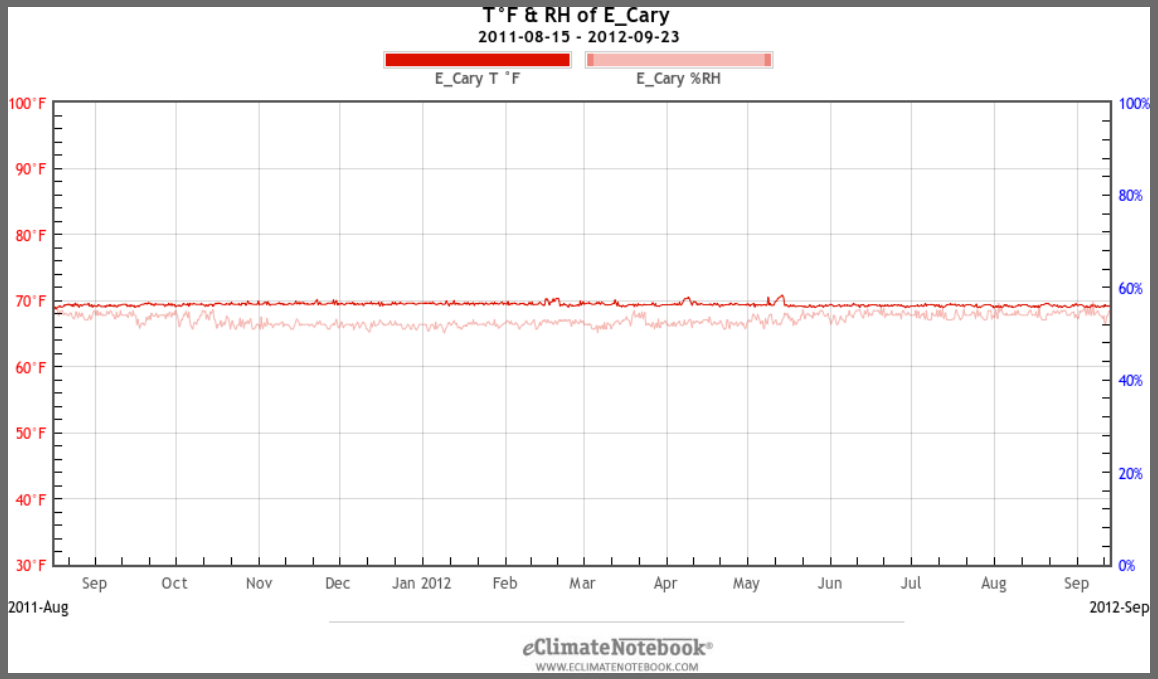
Managing Preservation Environment



IPI IMAGE PERMANENCE INSTITUTE

Environmental Control

Static approach to environmental control



IPI IMAGE PERMANENCE INSTITUTE

Environmental Control

Static approach to environmental control

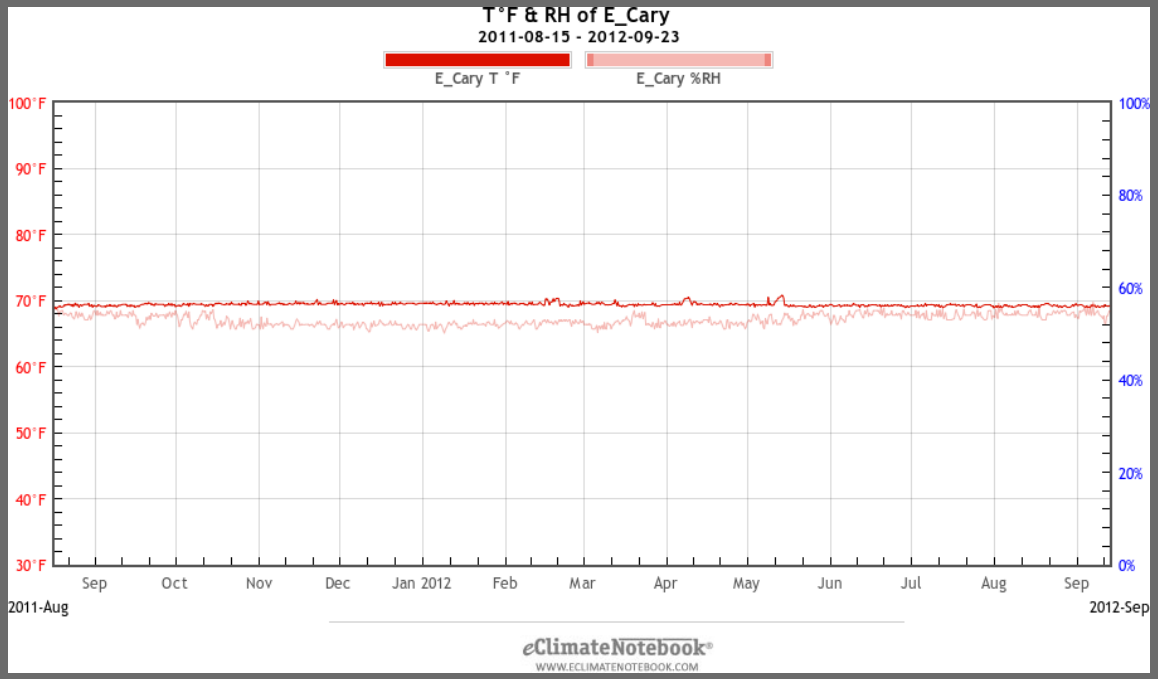


IMAGE PERMANENCE INSTITUTE

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

IPI IMAGE PERMANENCE INSTITUTE

What is the big picture?

- Move Towards Sustainability
  - Maintain high preservation quality
  - Save energy
  - Save money
  - Reduce carbon footprint

IPI IMAGE PERMANENCE INSTITUTE

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

IPI IMAGE PERMANENCE INSTITUTE

#1: Ideal T

First, address chemical stability. Keep T low

68F/20C & Higher	• High Risk for Chemical Decay for Most Materials • Increase in Biological Activity in Damp Conditons
55-67F/ 12-19C >	• Cool Temperatures Slow the Rate of Chemical Decay • Good for Most Materials Except Film and Color Photographs
40-54F/ 5-12C	• Beneficial for Film & Photograph Collections • Good for Most Materials Except Paintings
32F/0C Frozen Storage	• Best for film & photograph collections • Required for degrading acetate & nitrate film • Bad for CDs and DVDs

Safe Zones

IPI IMAGE PERMANENCE INSTITUTE

#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)

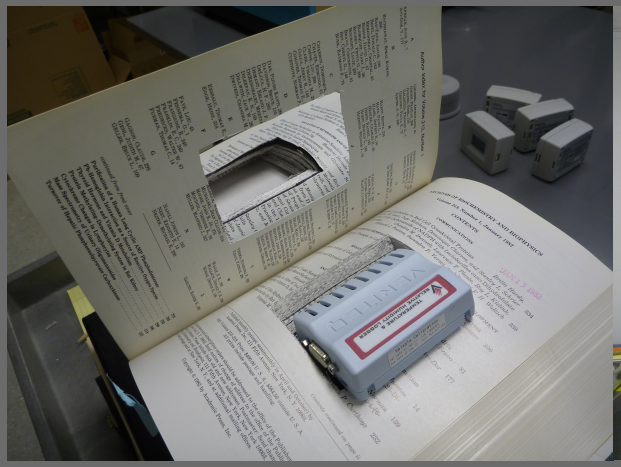
Safe Zone

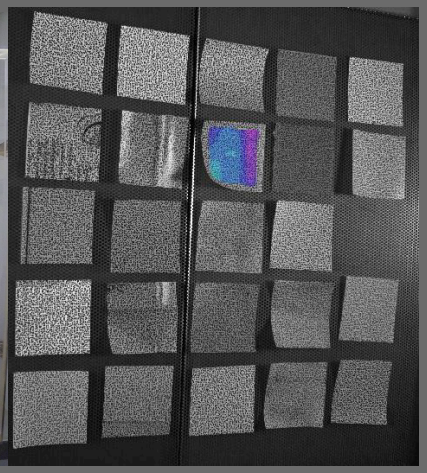
IPI IMAGE PERMANENCE INSTITUTE

Rhyme and Reason: The Research Behind It

Some Facts

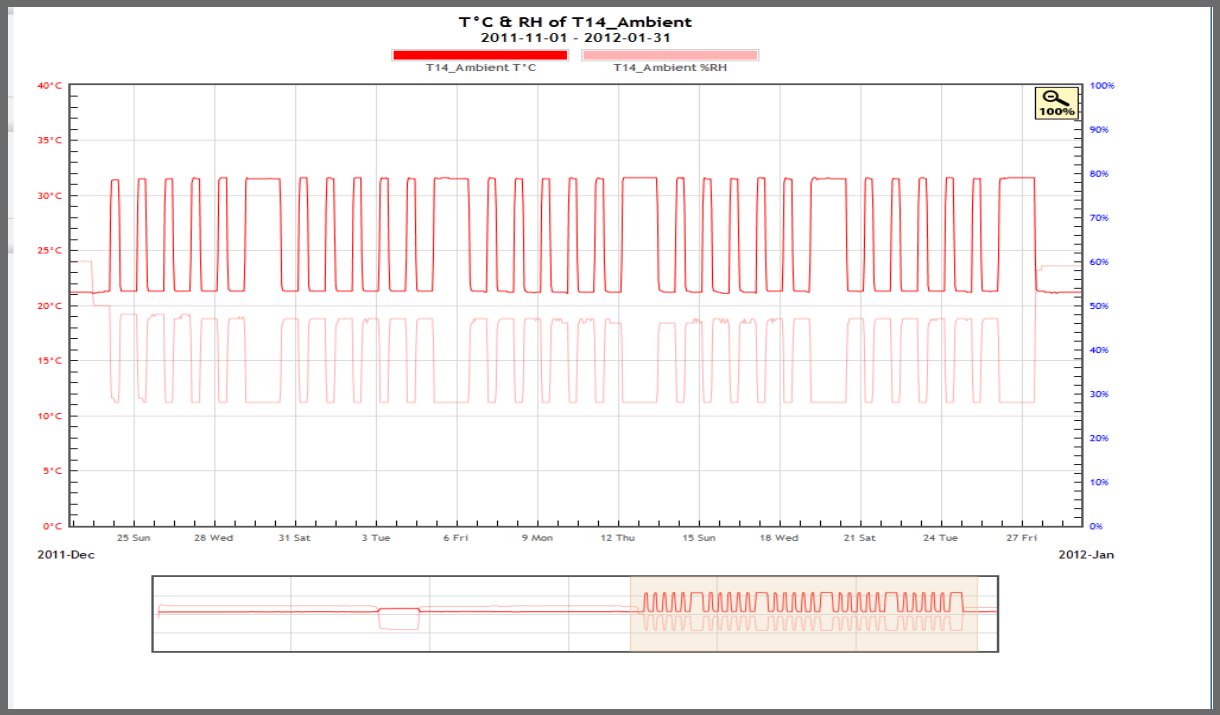
- Thermal equilibration is fast
- Moisture equilibration is slow
- Ambient RH will have impact over a long period of time
- Enclosures help buffer changes
- T, RH, Dew Point, and collection materials have a dynamic relationship

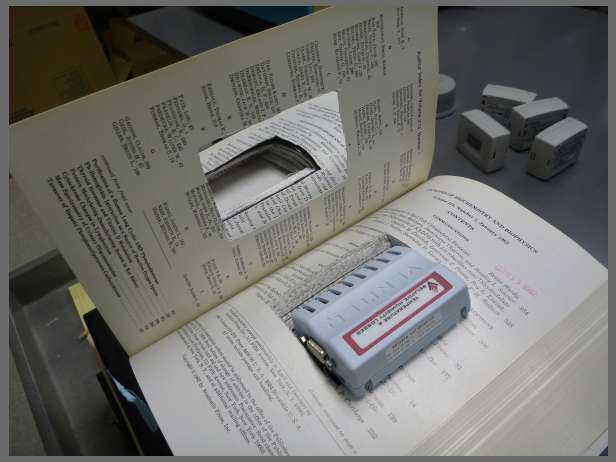




IPI IMAGE PERMANENCE INSTITUTE

Experimental Profile





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

IPI IMAGE PERMANENCE INSTITUTE

Enclosures

Metal edge cardboard box

Museum case

Portfolio box

IPI IMAGE PERMANENCE INSTITUTE

Thermal Equilibration

Fast!

Materials	Configuration	Time for 90% E
4 x 5-in. sheet film	Stack of 500 sheets in metal drawer	6.25 hours
3.5 x 5-in. RC prints	1,000 prints in cardboard box	4 hours

IPI IMAGE PERMANENCE INSTITUTE

Moisture Equilibration

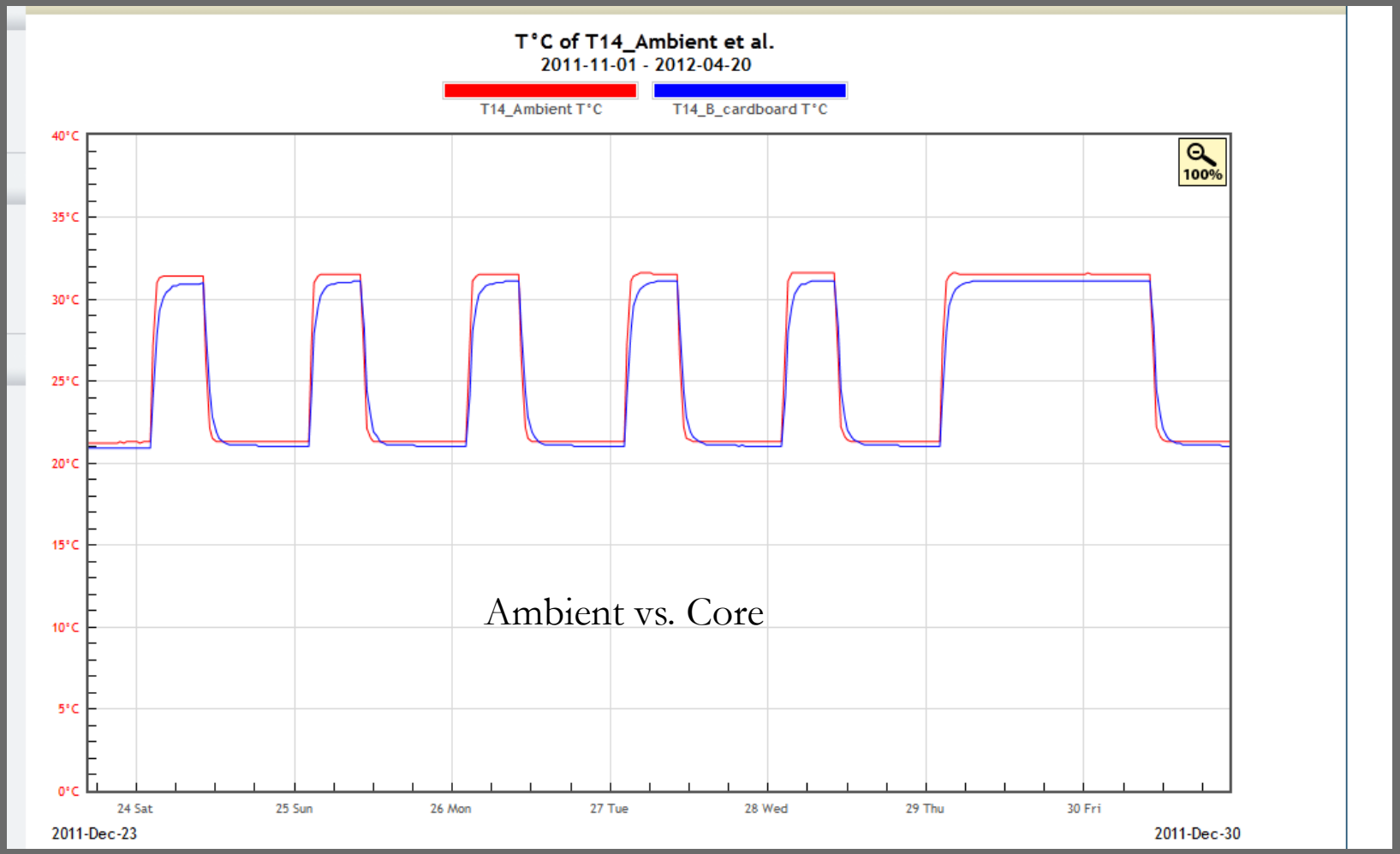
Slow!

Materials	Enclosures	90% Equilibration
Hardcover Book	Book on shelf	One month
35mm film	Metal can	Six months

Moisture Equilibration at 20˚C (68˚F)

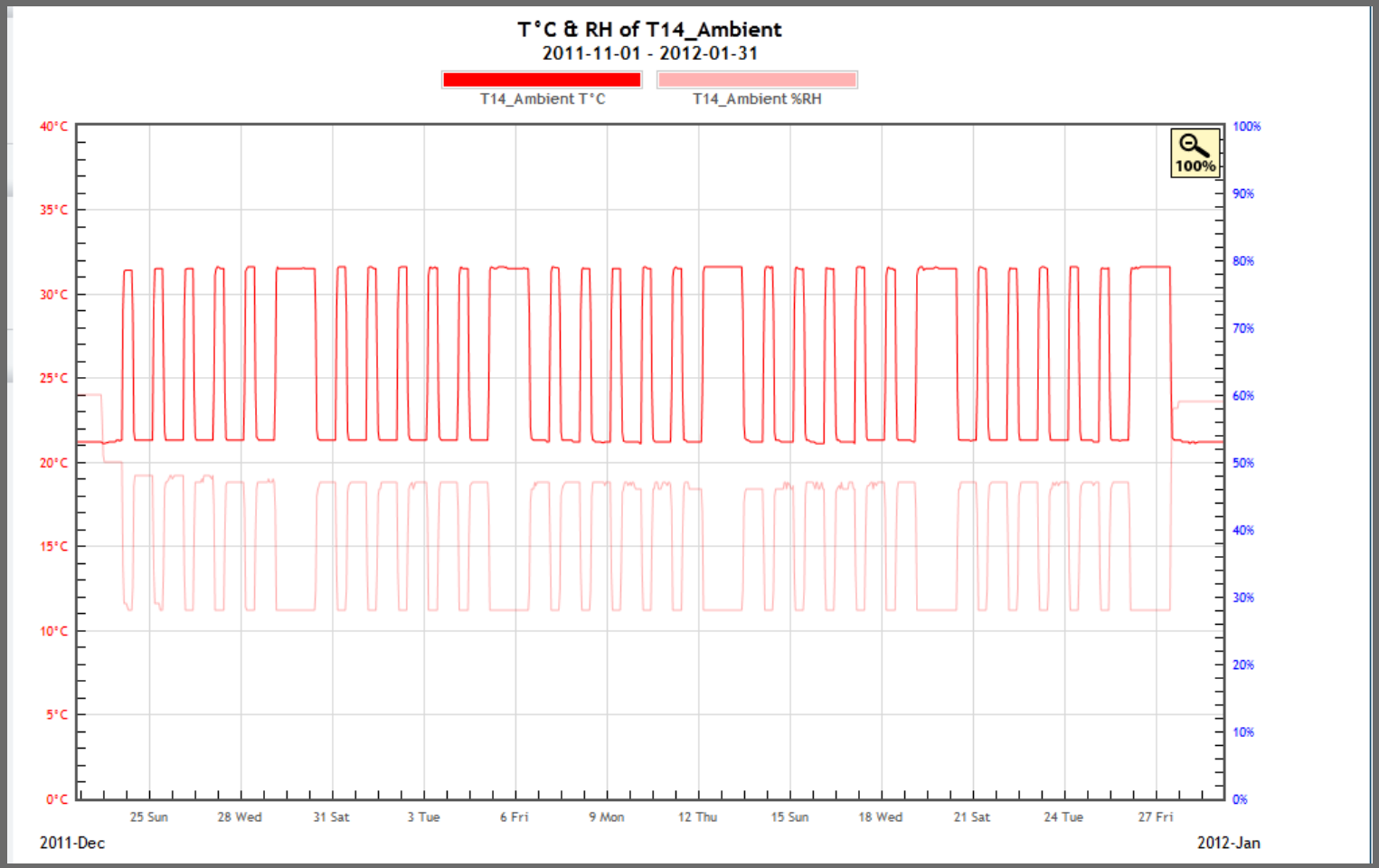
IPI IMAGE PERMANENCE INSTITUTE

T Equilibration



IPI IMAGE PERMANENCE INSTITUTE

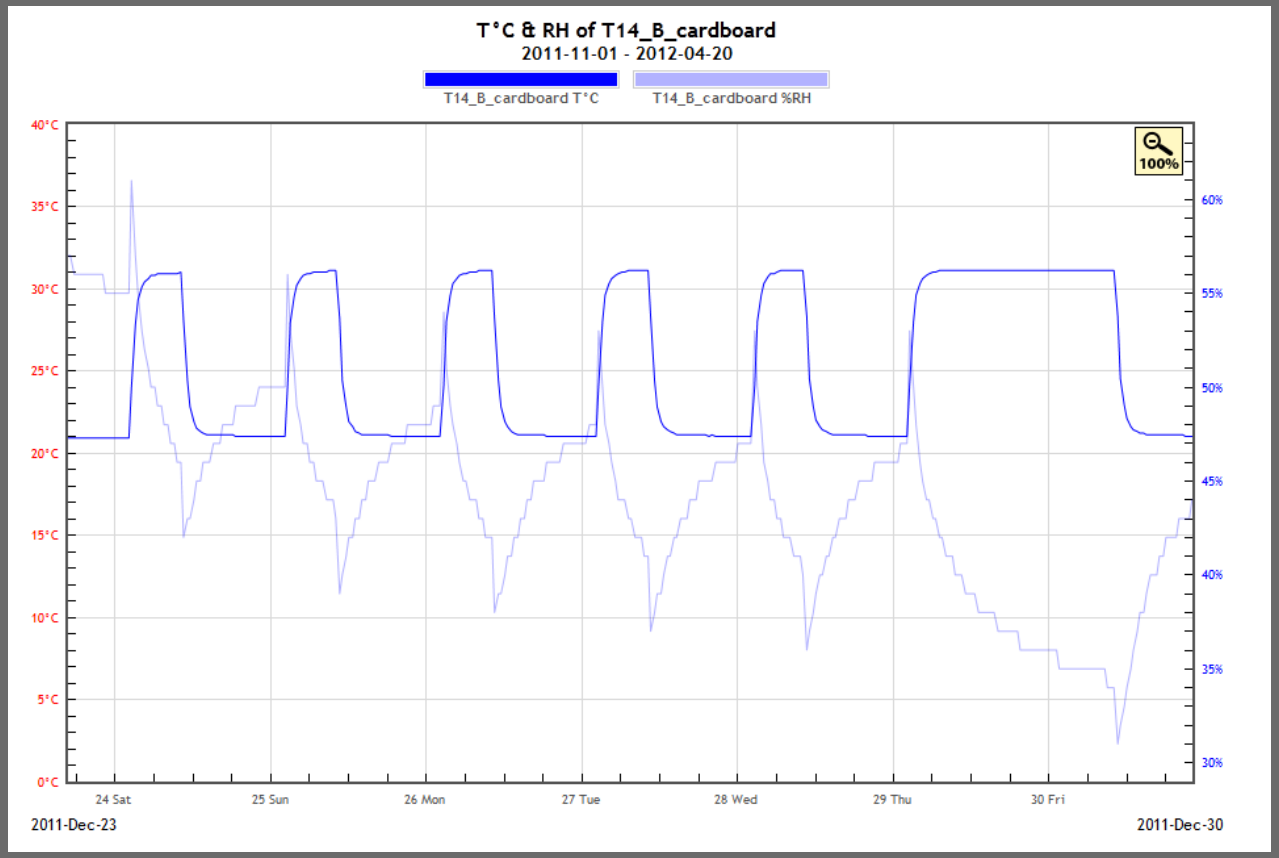
Experiment Reminder



IPI IMAGE PERMANENCE INSTITUTE

RH Equilibration

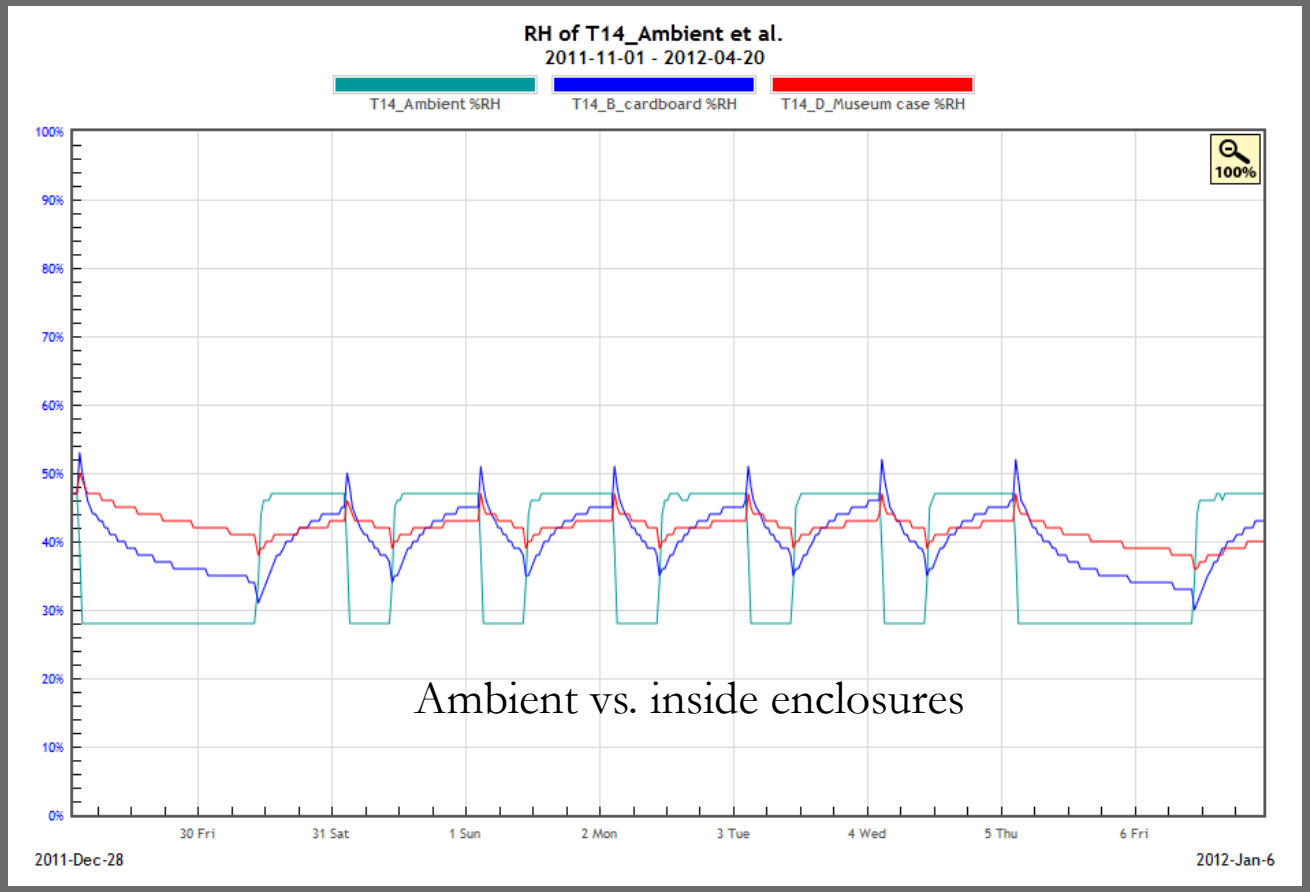
Changes in Microenvironments: matted photographs in a cardboard box



IPI IMAGE PERMANENCE INSTITUTE

RH Equilibration

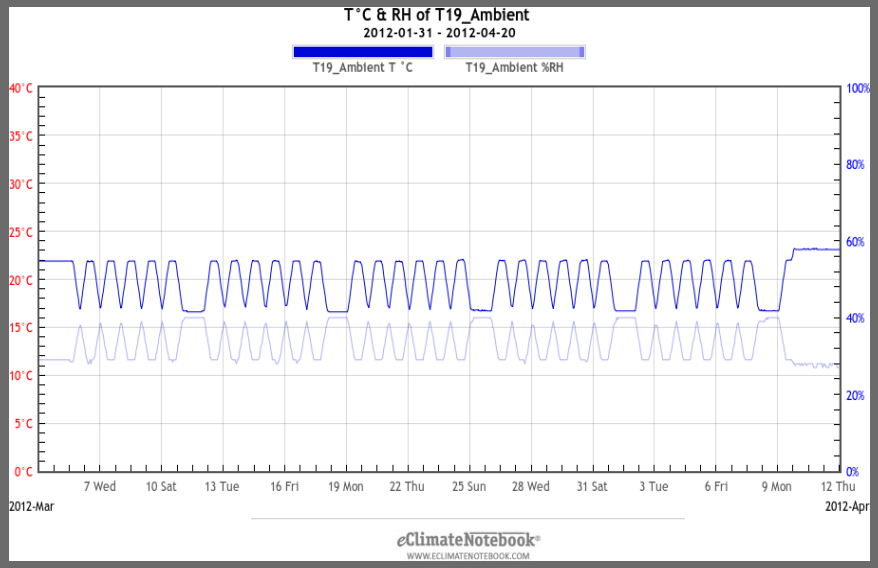
Changes in Microenvironments: cardboard box and museum case

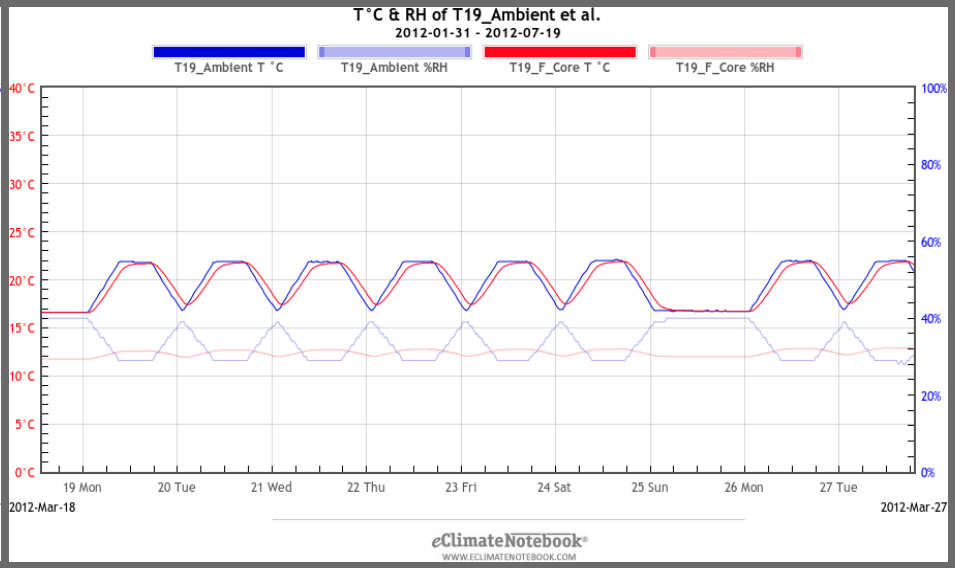


IPI IMAGE PERMANENCE INSTITUTE

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

IPI IMAGE PERMANENCE INSTITUTE

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

IPI IMAGE PERMANENCE INSTITUTE

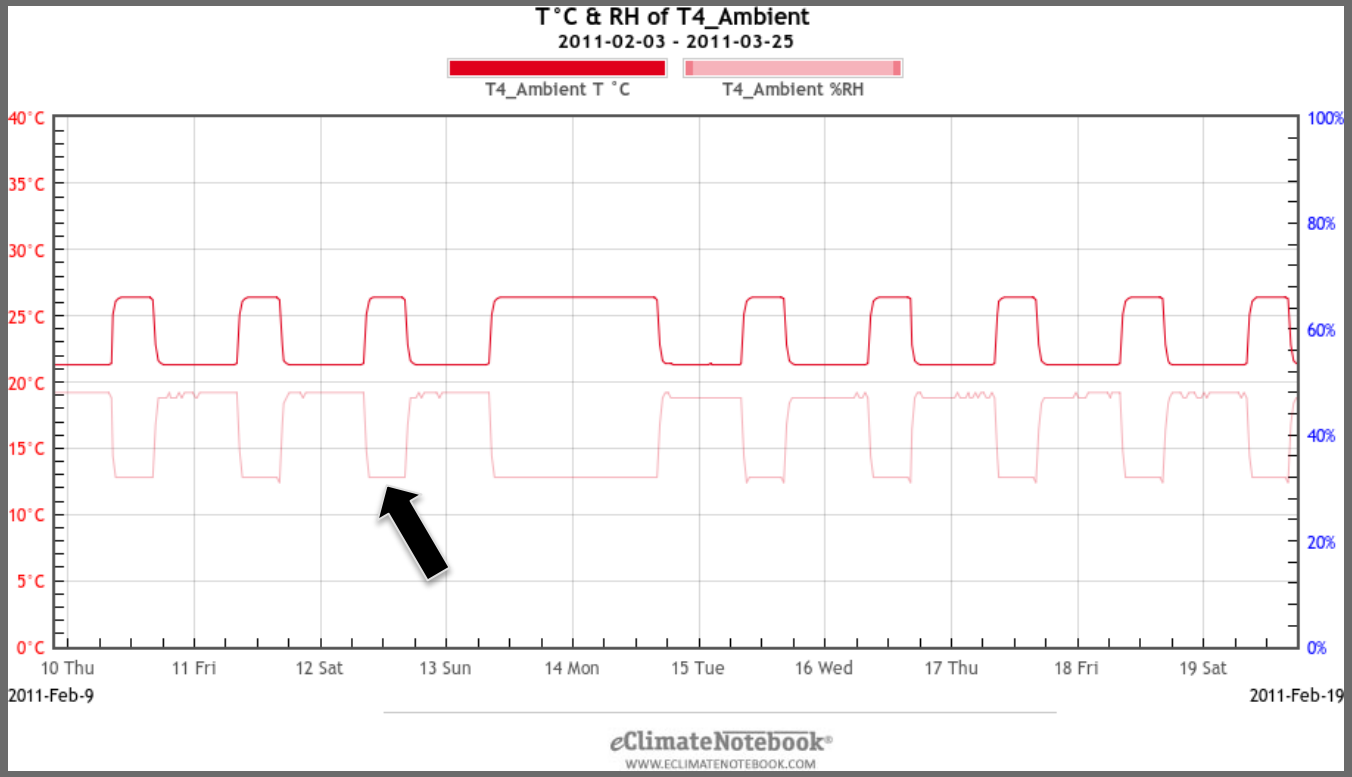
Relationship: T, RH, Dew Point

T ↓ RH ↑

This phenomenon occurs primarily in an empty room

IPI IMAGE PERMANENCE INSTITUTE

Relationship: T, RH, Collection

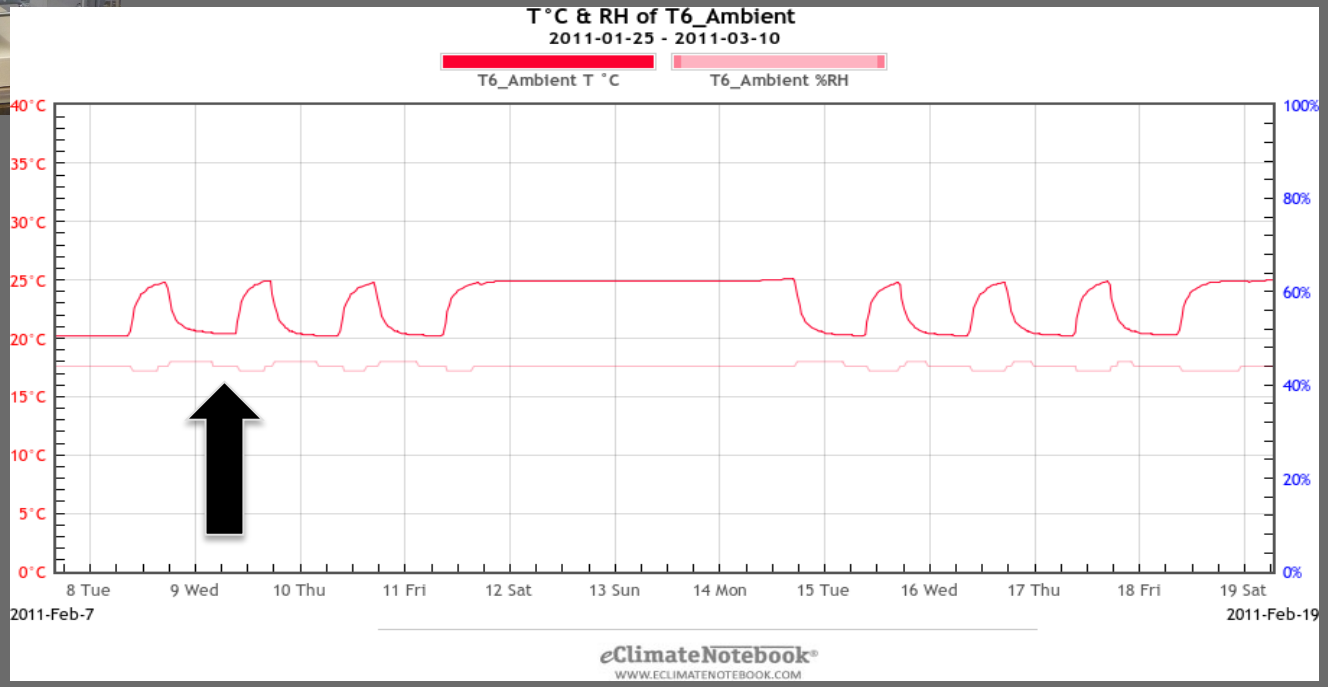


Empty, sealed space
T change only

IPI IMAGE PERMANENCE INSTITUTE

Relationship: T, RH, Collection

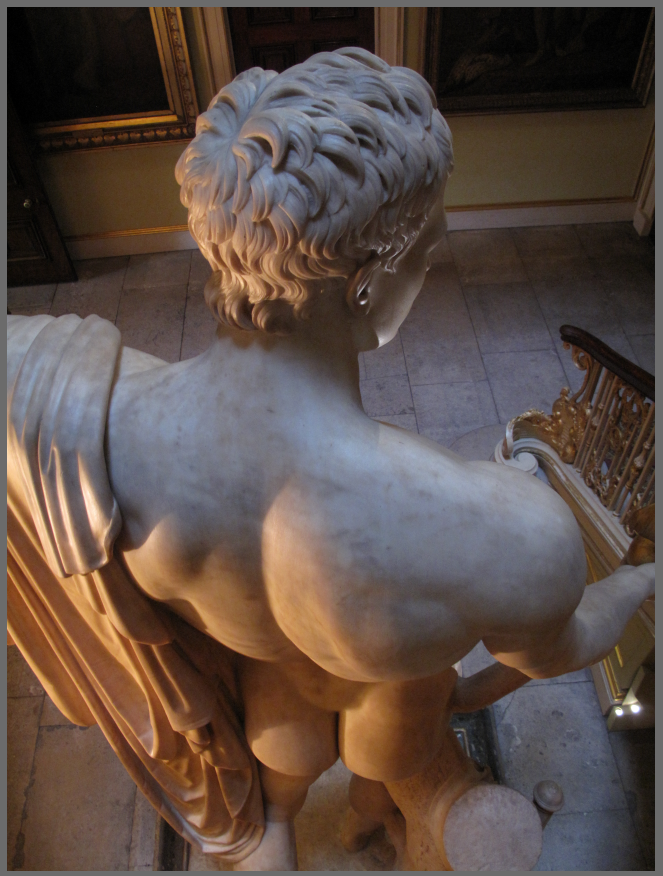
Full Space



IPI IMAGE PERMANENCE INSTITUTE

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"



IPI IMAGE PERMANENCE INSTITUTE

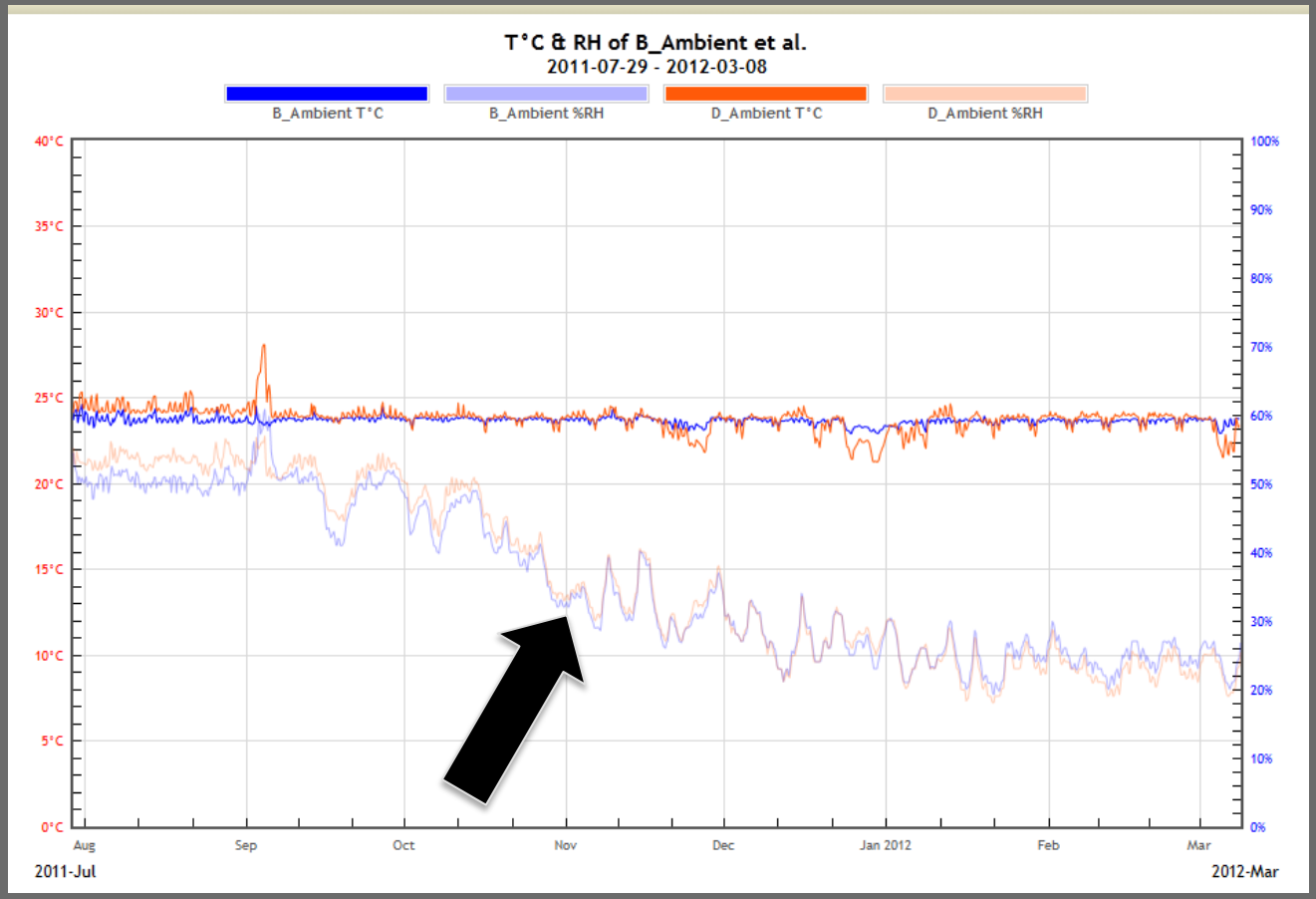
Daily Shutdown

Night and weekend shut down of HVAC

Zone			HVAC Operation Weekdays
A	Shutdown during 6 hours	Cool to 30°C Heat to 13°C	OFF for up to 6 hours
B	No Shutdown.	21°C	ON
C	Shutdown during 8 hours	Cool to 30°C Heat to 13°C	OFF for up to 8 hours
D	Shutdown during 8 hours	Cool to 32°C Heat to 10°C	OFF for up to 8 hours
E	Continuous Temp. and RH control		ON

IPI IMAGE PERMANENCE INSTITUTE

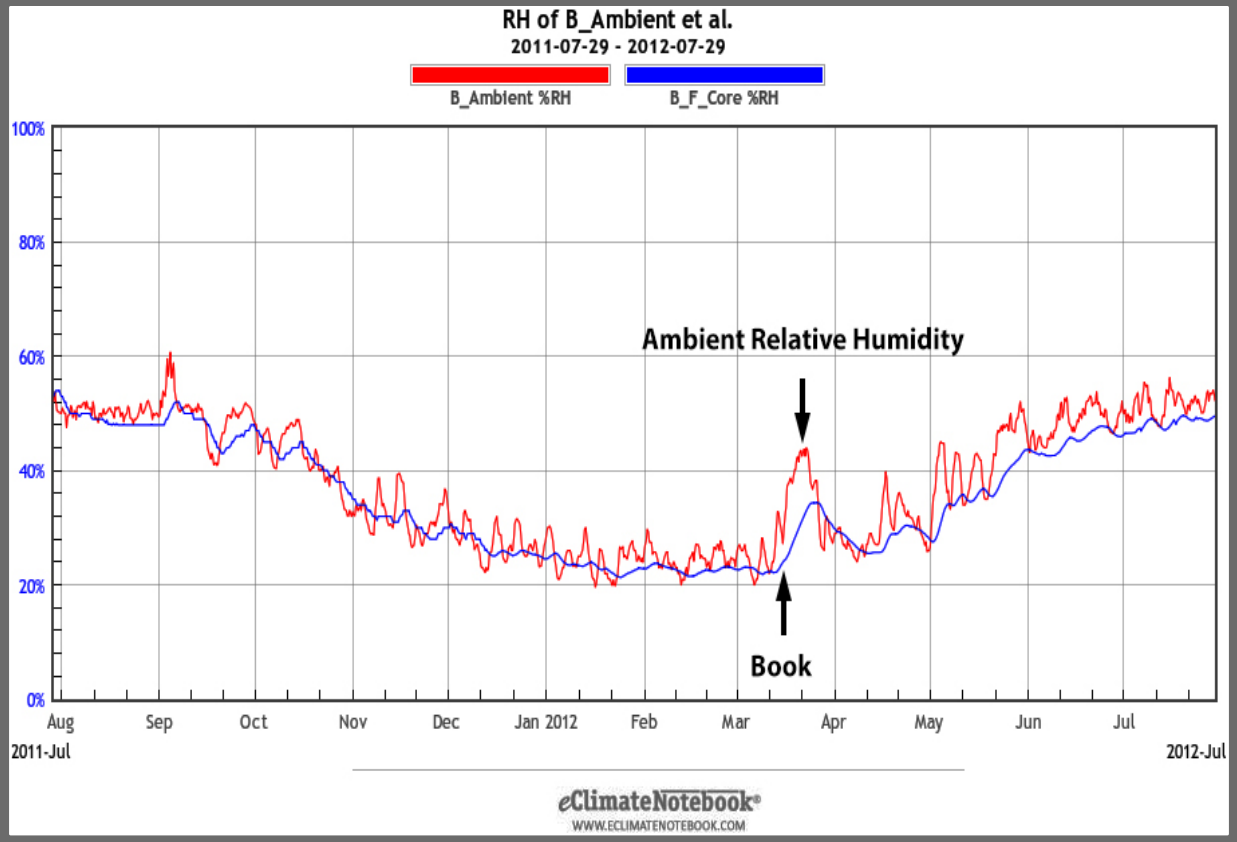
Daily Shutdown: T Control Only



Ambient environment: no setback (B) and 8 hour setback (D)

IPI IMAGE PERMANENCE INSTITUTE

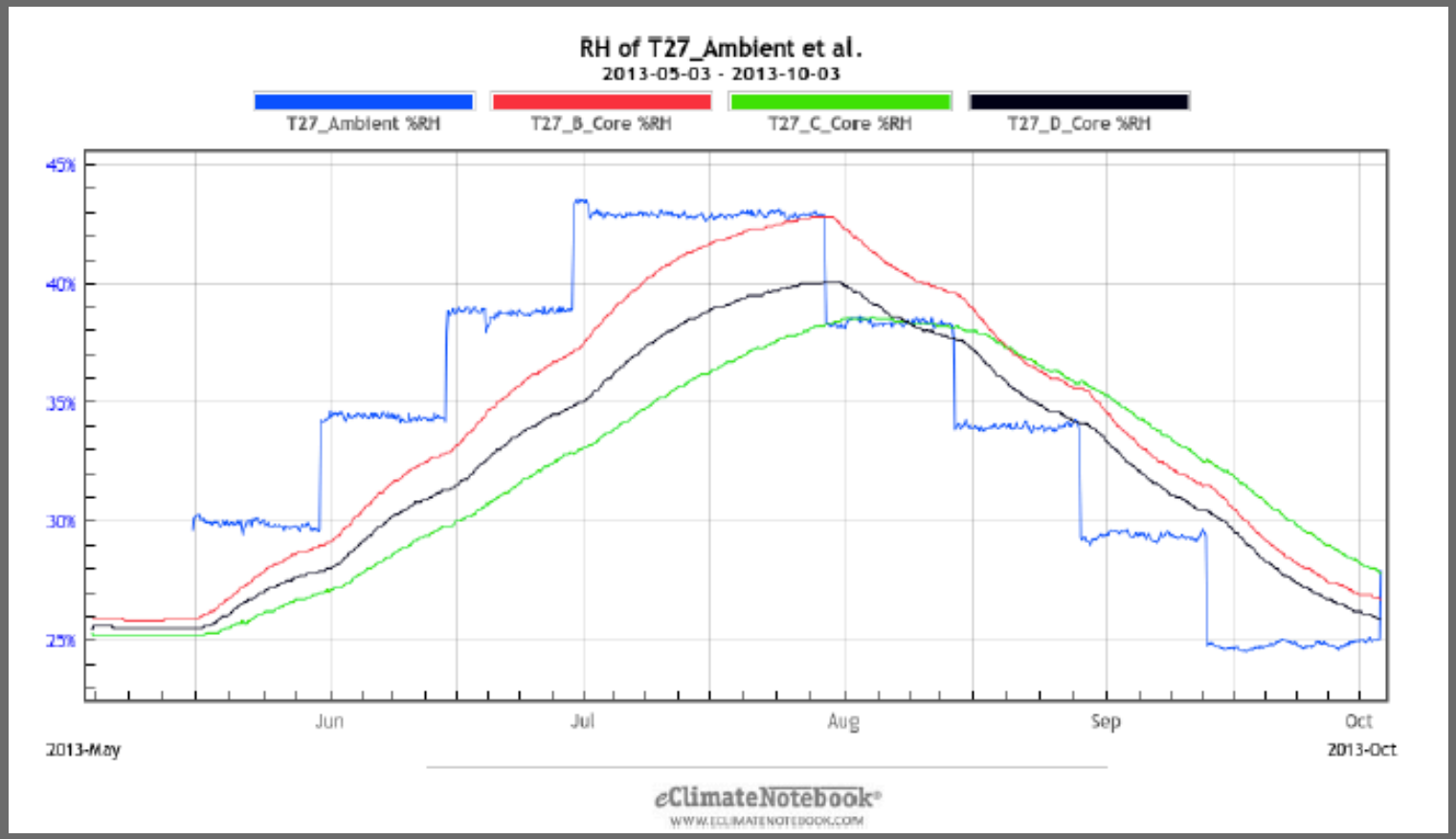
Moisture Equilibration is Slow



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

IPI IMAGE PERMANENCE INSTITUTE

Enclosures Matter

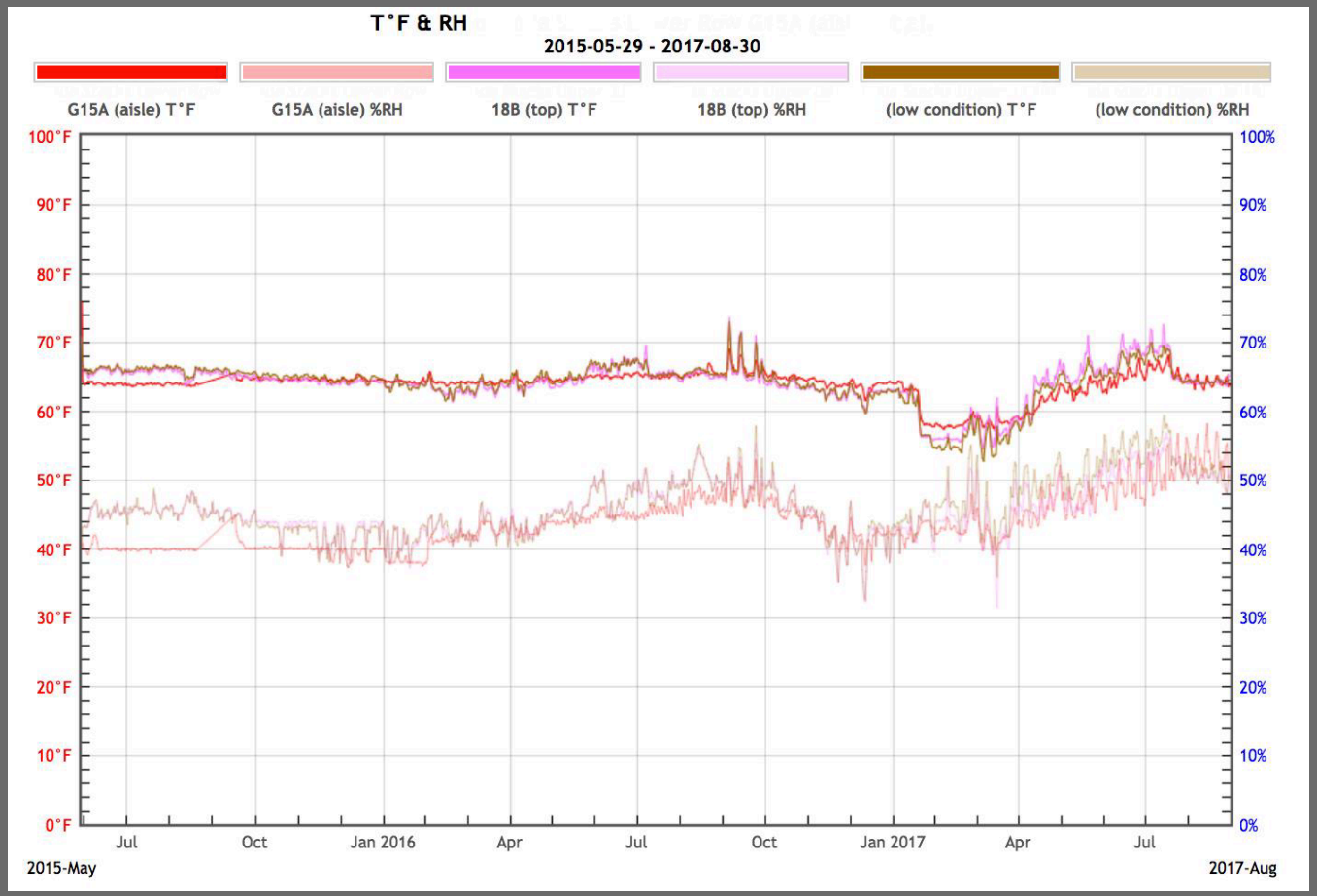


Stepped RH profile at 20°C on RH level at the core of matted photographs in different enclosure types

B: cardboard box; C: portfolio box; D: museum case

IPI IMAGE PERMANENCE INSTITUTE

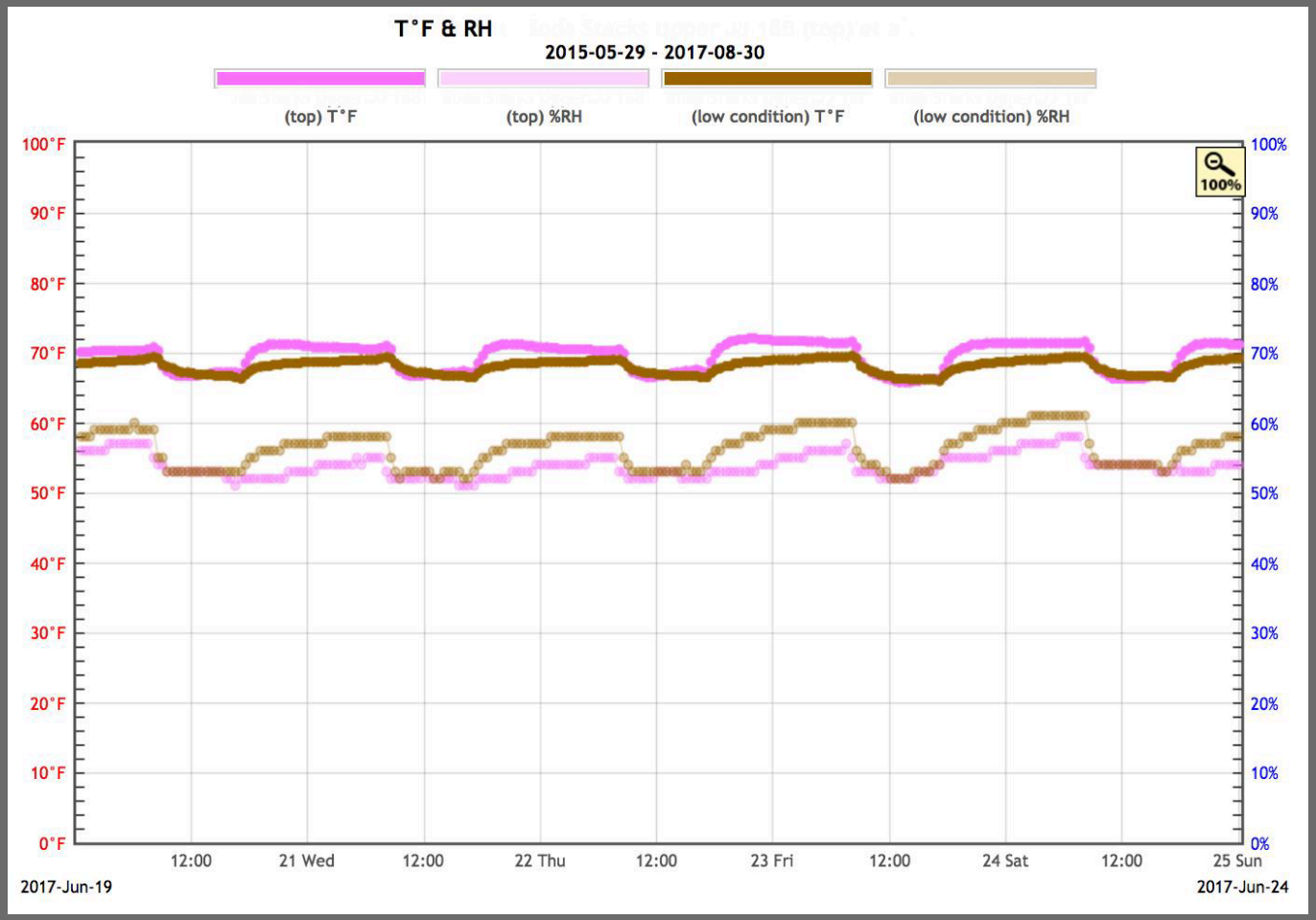
Case Study: Setbacks and Shutdowns



One Year

IPI IMAGE PERMANENCE INSTITUTE

Case Study: Setbacks and Shutdowns



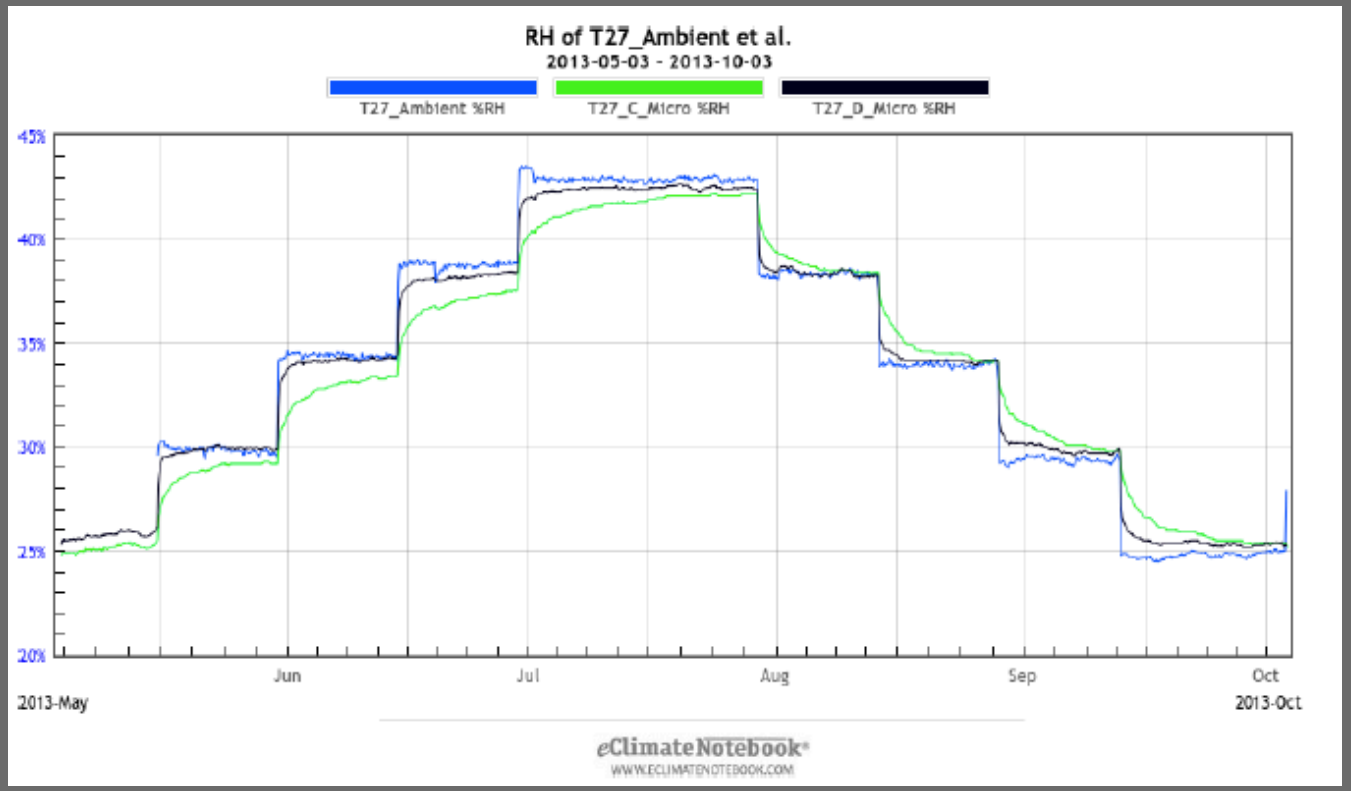
One Day

IPI IMAGE PERMANENCE INSTITUTE

Further Research

- What about that moisture gradient, aka the "skin"?
- What about about that self-buffering phenomenon?
- What if I don't have RH control?

Moisture Gradient



Stepped RH profile at 20ºC on RH level in the microenvironment of matted photographs in different enclosure types

C: portfolio box; D: museum case

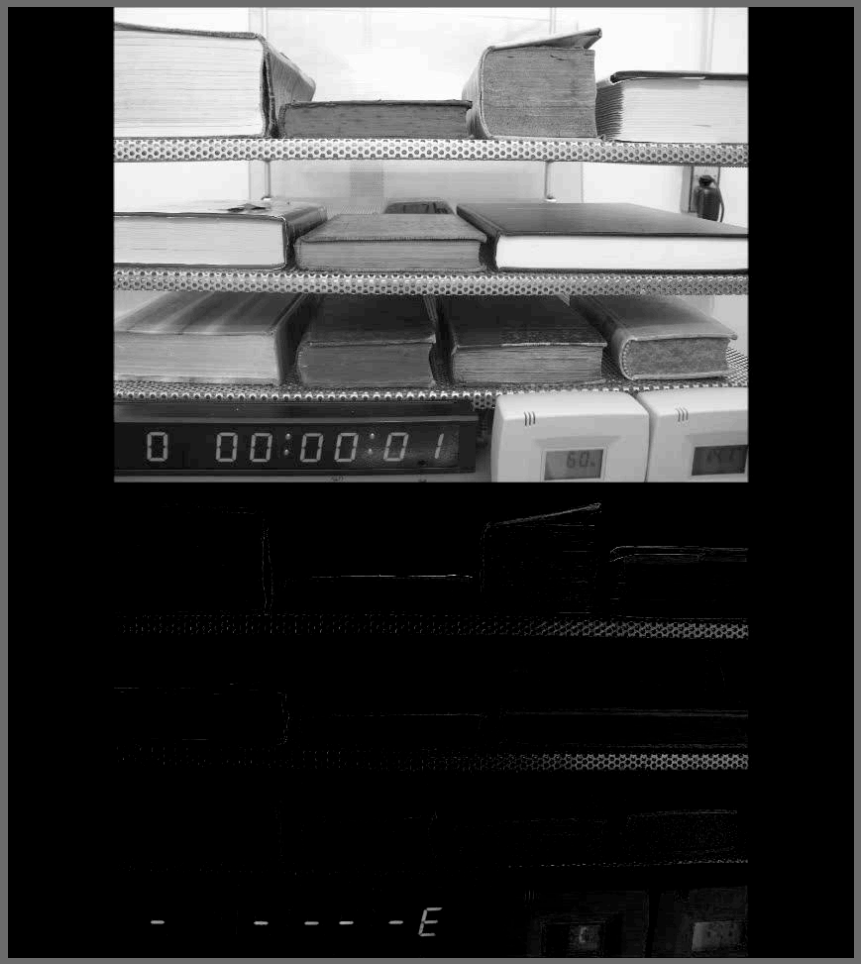
IPI IMAGE PERMANENCE INSTITUTE

Mechanical Deformation: Digital Image Correlation (DIC)

- Complex, composite objects
- Variety of materials
- Different hygroexpansivities
  - Absorbs moisture and expands as RH increases

IPI IMAGE PERMANENCE INSTITUTE

“Skin” of the Book

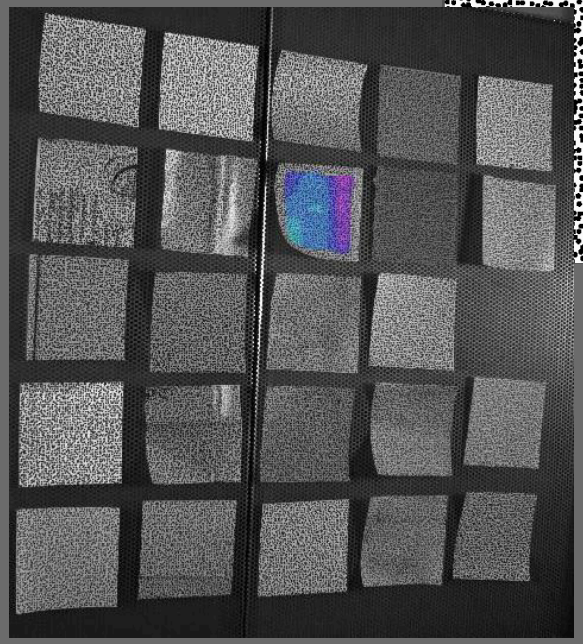


60%-25%-60% RH

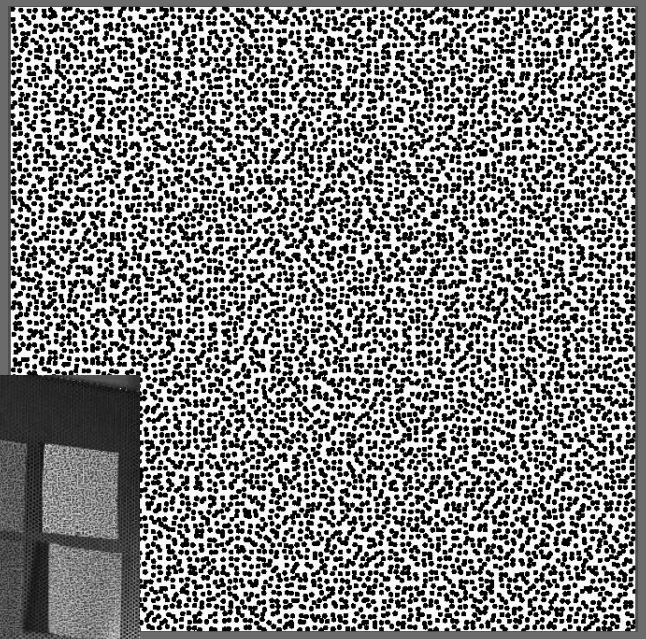
IMAGE PERMANENCE INSTITUTE

DIC

Experimental Set up



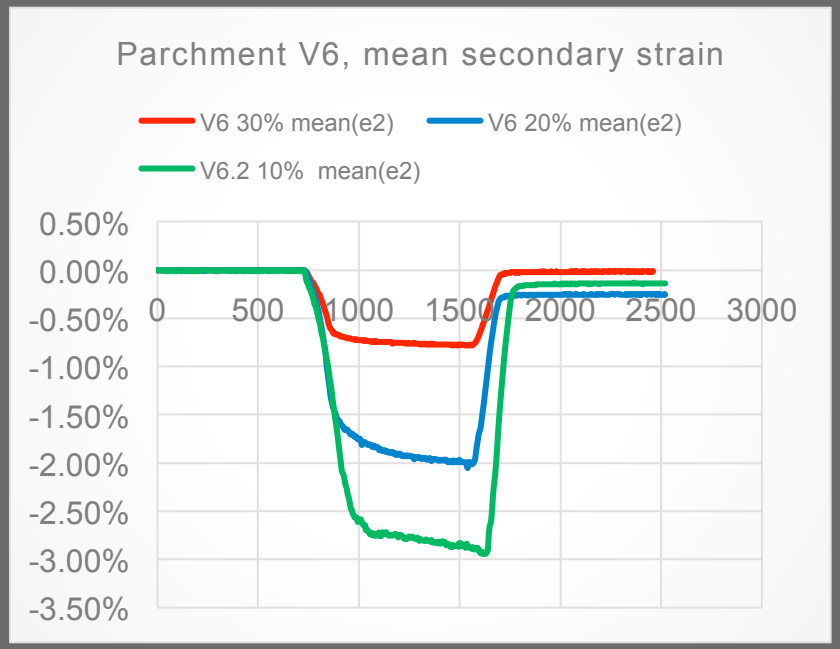
2D Model of Parchment

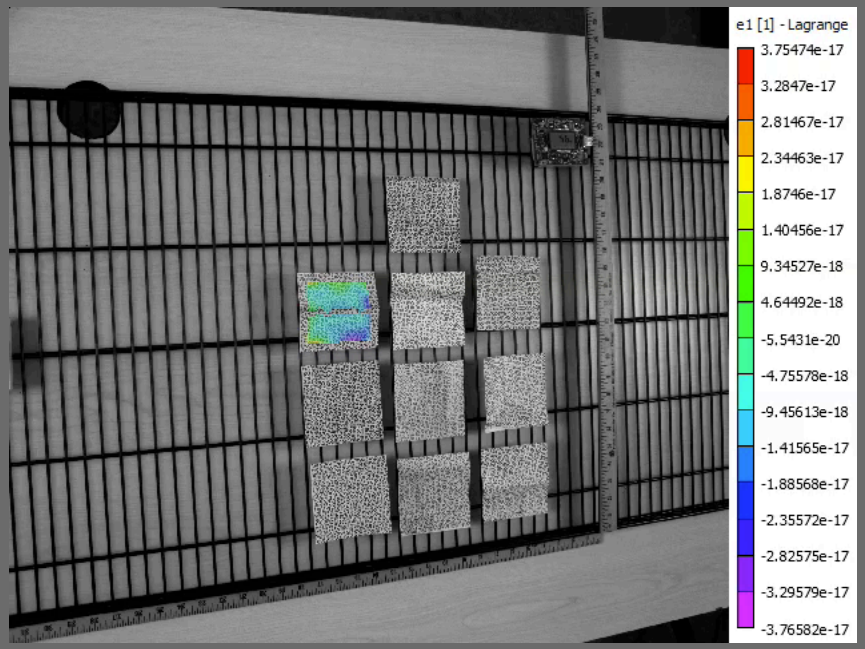


Random Speckle Pattern

IPI IMAGE PERMANENCE INSTITUTE

Mechanical Deformation

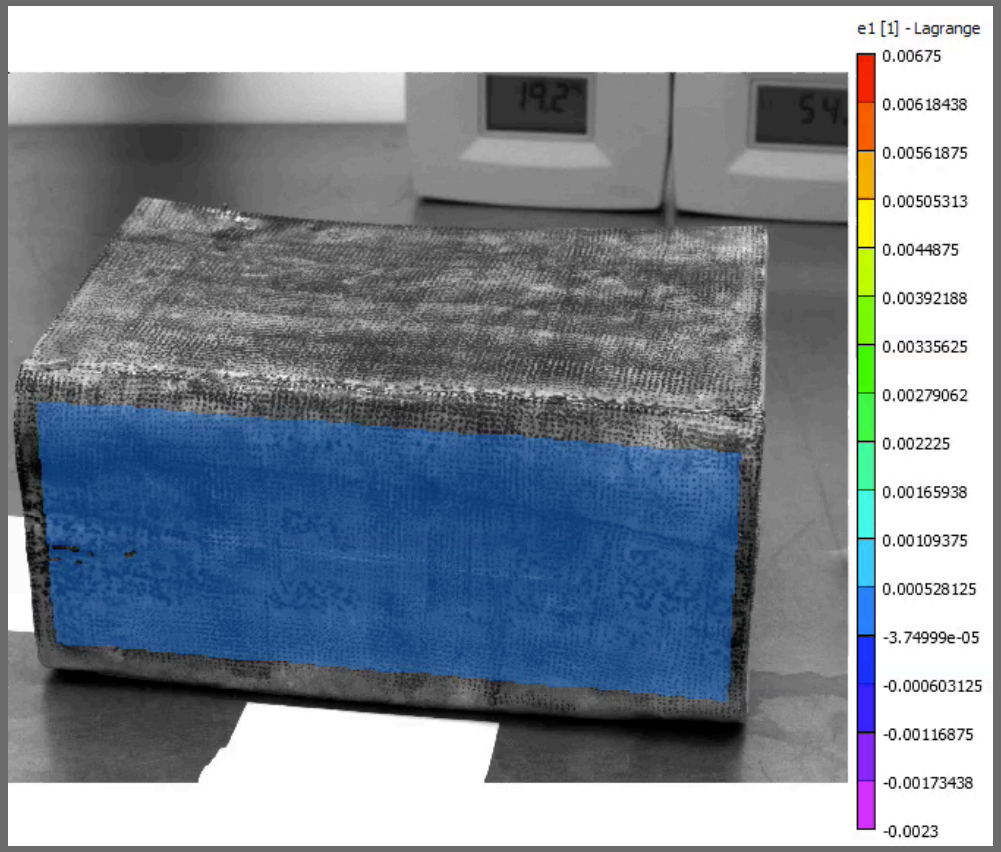




Parchment Samples
Profile: 50-30-50 %RH

IPI IMAGE PERMANENCE INSTITUTE

DIC

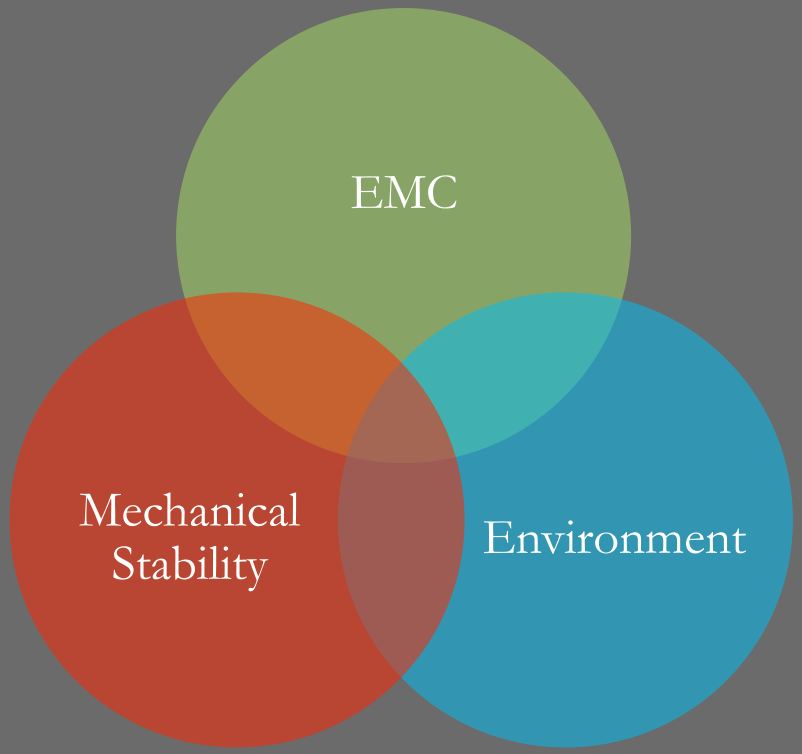


Preliminary DIC study vellum bound book

IPI IMAGE PERMANENCE INSTITUTE

Buffering & T control

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



IPI IMAGE PERMANENCE INSTITUTE

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

IPI IMAGE PERMANENCE INSTITUTE

Thank You

National Endowment for the Humanities
Division of Preservation and Access

IPI IMAGE PERMANENCE INSTITUTE