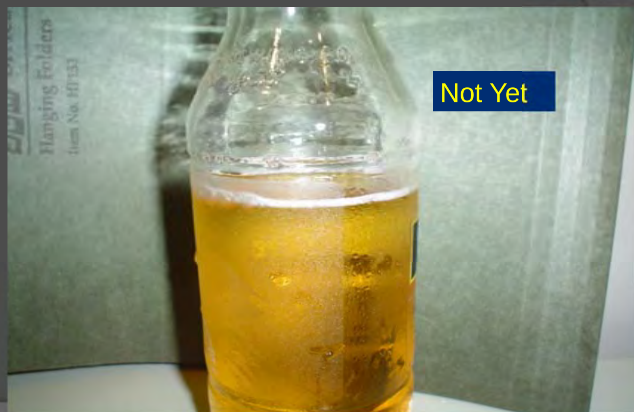
$E = fd(u)\ (E_s - E_a)$



Drying Strategies For Complex Materials & Structures

- RH is for Sissies..

- RH is a comfort index

how about…

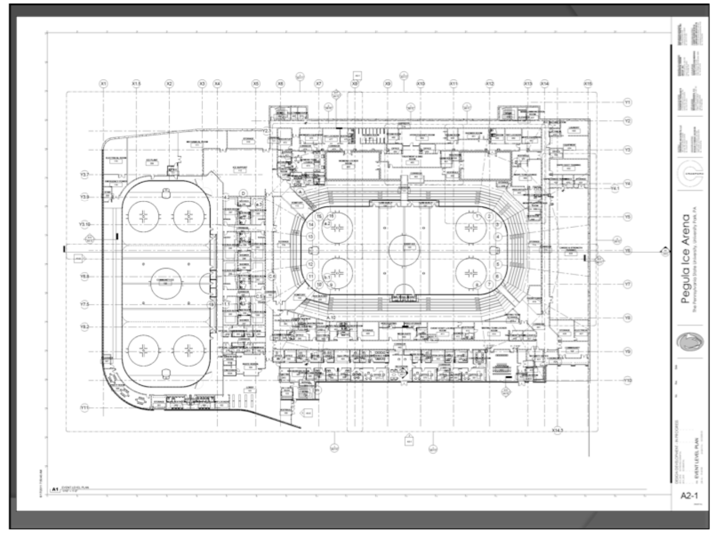
- Heat index

How do you feel

Applications

ICE ARENAS

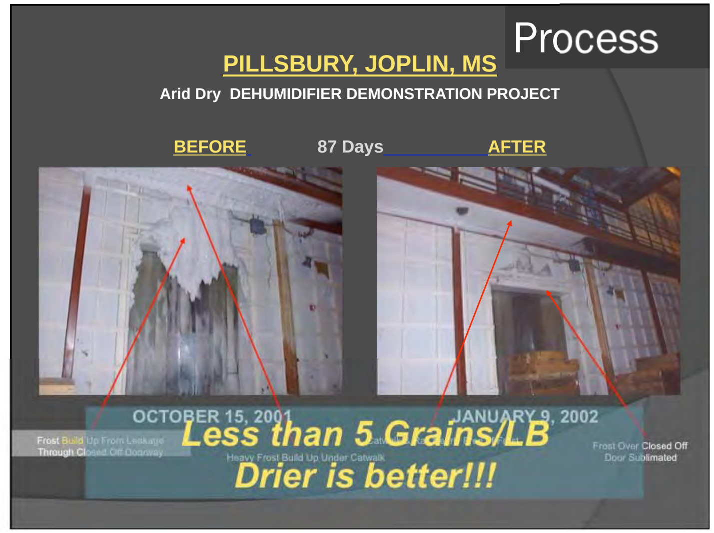

Applications
ICE ARENAS
36° F Dewpoint

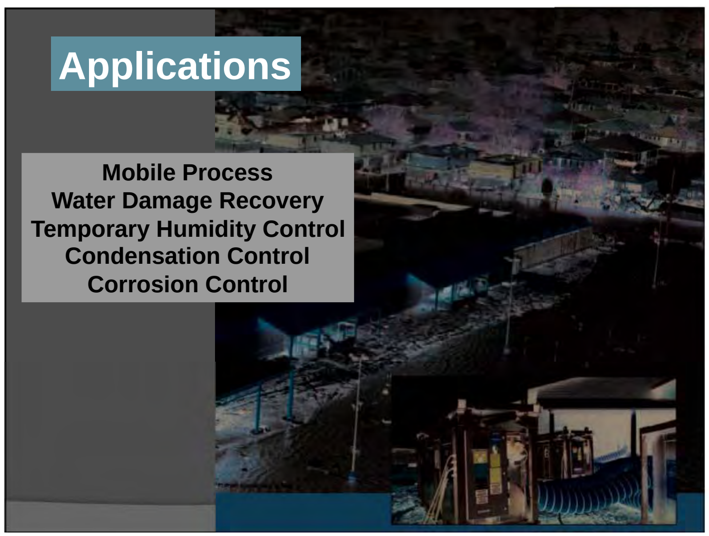

Pegula Ice Arena
A2-1

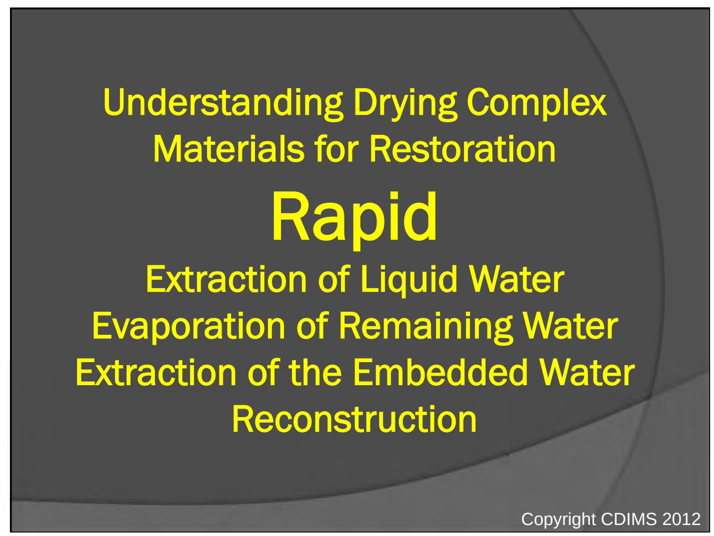

Applications
PROCESS
26 to 28° F Dewpoint
700 Foot Indoor Ski Hill with Play Area and Mall
Beijing, China

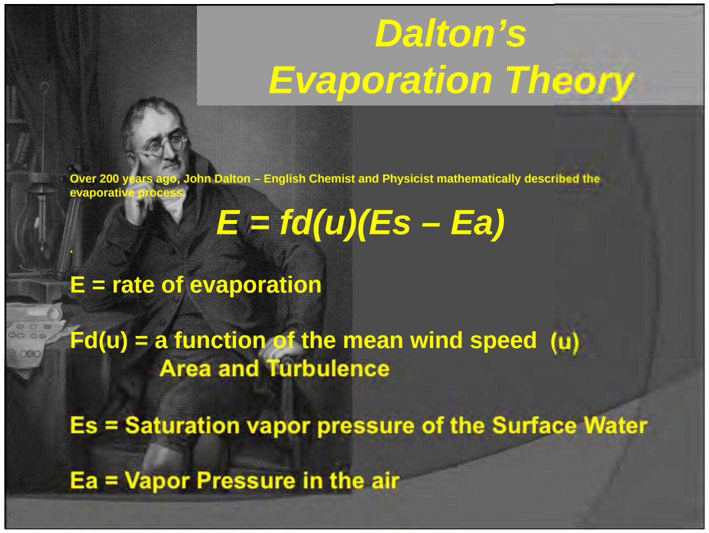

Applications
PROCESS
Automotive Test Cell Air System
-28 F to 128 F 2 Gns/Lb RH to 165 Gns/LB

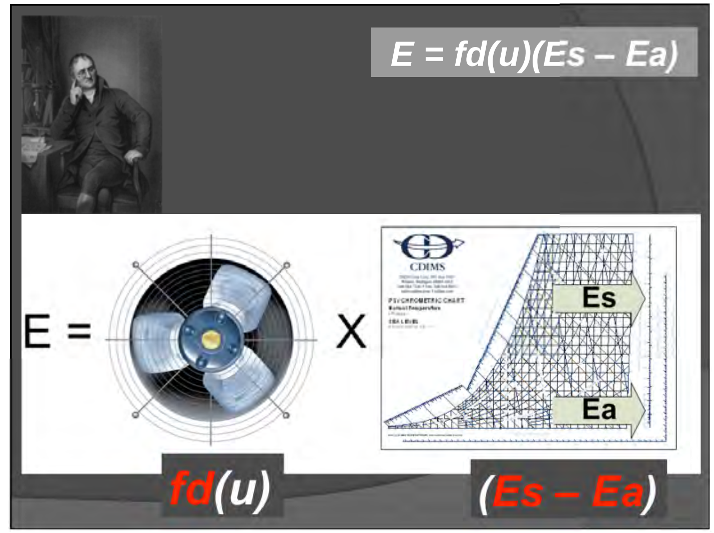

Applications
PROCESS
Food Process
35 F to 40F
Recovery after Wash-Down
Less than 5 Grains/LB
Then
Maintain 32 to 36° F Dewpoint

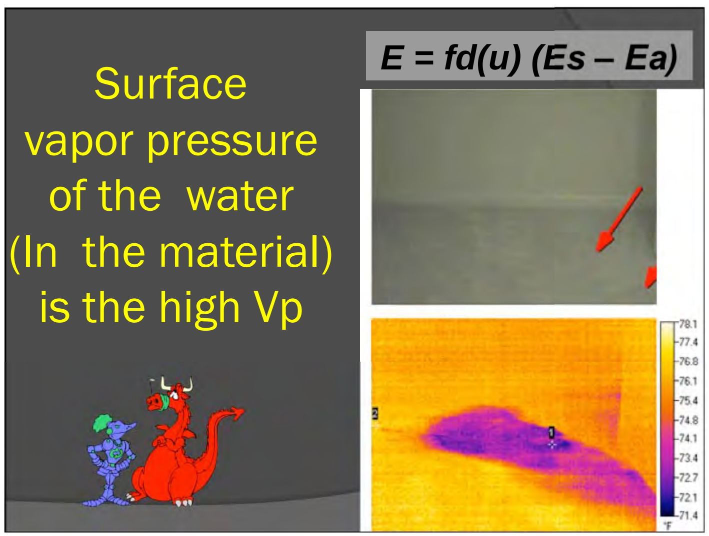

Process
PILLSBURY, JOPLIN, MS
Arid Dry DEHUMIDIFIER DEMONSTRATION PROJECT
BEFORE
87 Days
AFTER
OCTOBER 15, 2001
JANUARY 9, 2002
Frost Build Up From Leakage Through Closed Off Doorway
Heavy Frost Build Up Under Catwalk
Frost Over Closed Off Door Sublimated
Less than 5 Grains/LB
Drier is better!!!

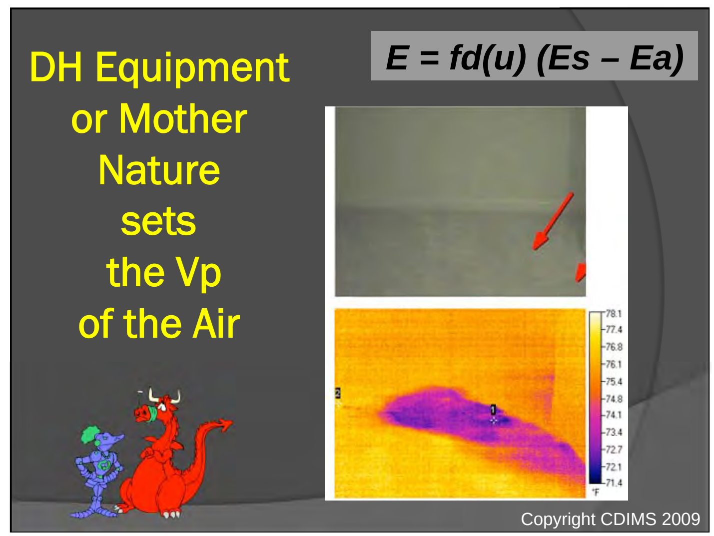

Applications
Mobile Process
Water Damage Recovery
Temporary Humidity Control
Condensation Control
Corrosion Control

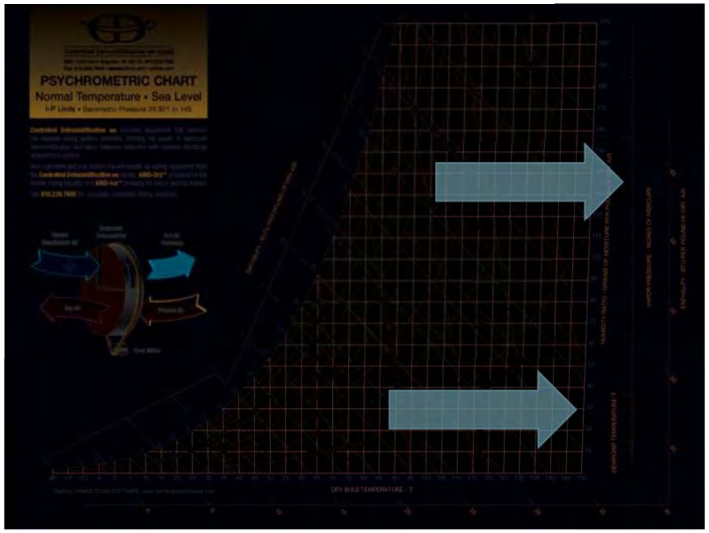

Understanding Drying Complex Materials for Restoration
Rapid
Extraction of Liquid Water
Evaporation of Remaining Water
Extraction of the Embedded Water
Reconstruction
Copyright CDIMS 2012


Dalton's
Evaporation Theory
Over 200 years ago, John Dalton – English Chemist and Physicist mathematically described the evaporative process.
E = fd(u)(Es – Ea)
E = rate of evaporation
Fd(u) = a function of the mean wind speed (u)
Area and Turbulence
Es = Saturation vapor pressure of the Surface Water
Ea = Vapor Pressure in the air


E = fd(u)(Es – Ea)
E =
X
Es
Ea
fd(u)
(Es – Ea)


E = fd(u) (Es – Ea)
Surface
vapor pressure
of the water
(In the material)
is the high Vp


E = fd(u) (Es – Ea)
DH Equipment
or Mother
Nature
sets
the Vp
of the Air
Copyright CDIMS 2009



Some would say blow hot air at it?

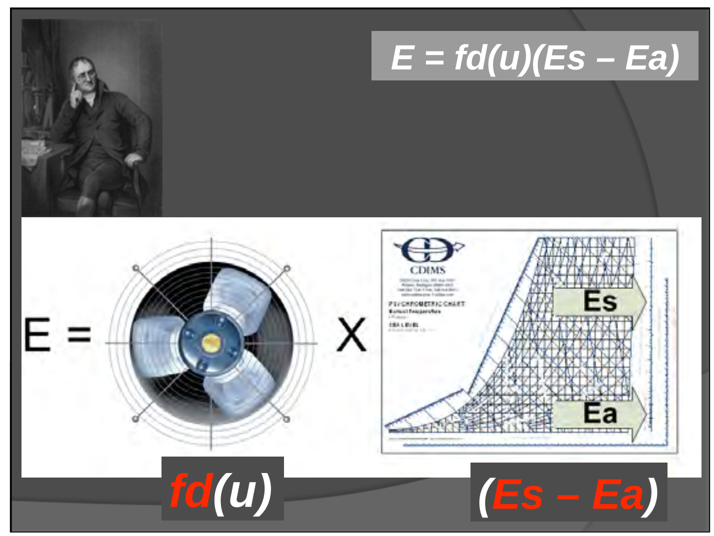
Air is a poor conductor of heat energy…

Hard to add Heat Energy to Water

would you use a hair dryer to boil a pot of water

Some would say blow hot air at it?

It is useful to replace evaporation cooling effect..

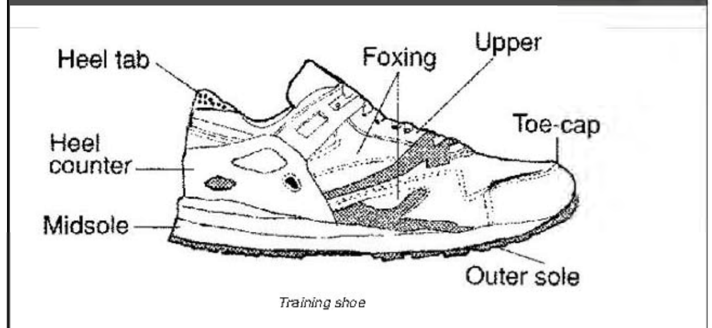


So after you evaporate the easy water…(Surface Water)

the water embedded in materials is left
(Return Material To Equilibrium)

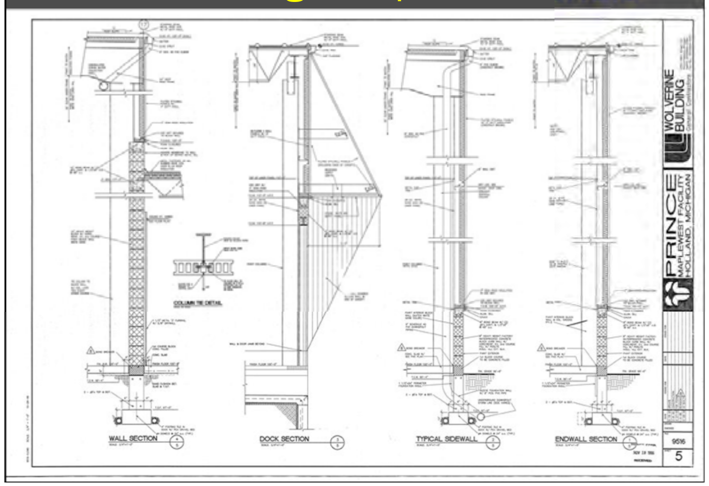
Typically a low percentage of the original content.

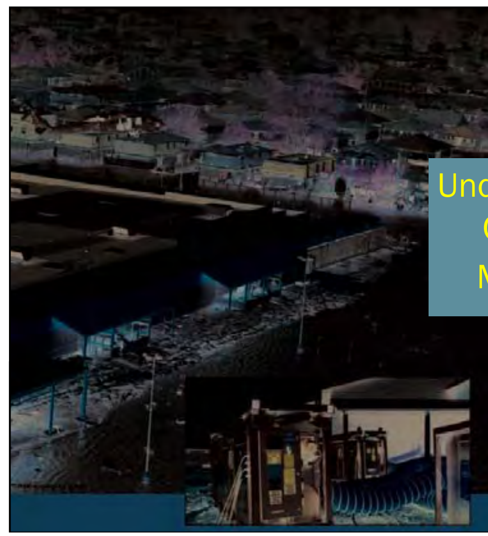
Understanding Complex Materials



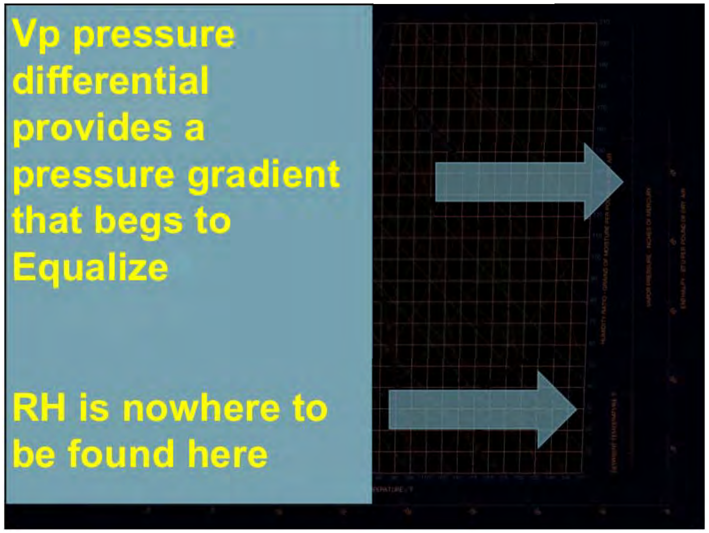
Courtesy of Ansewers.com

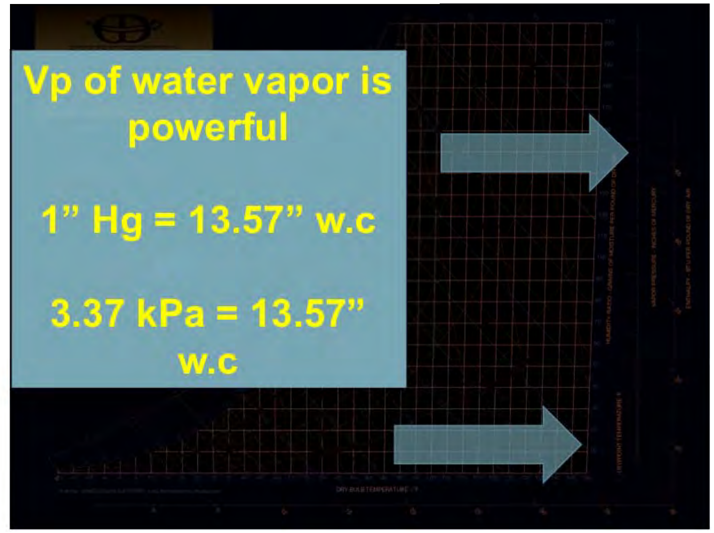
Understanding Complex Materials

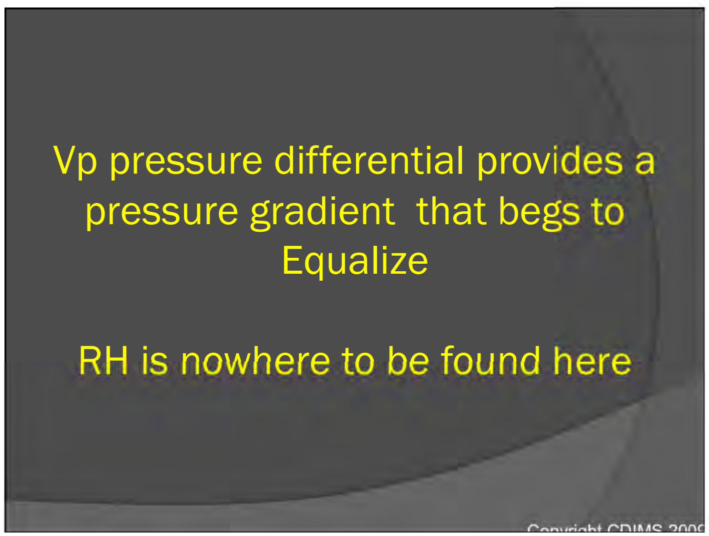


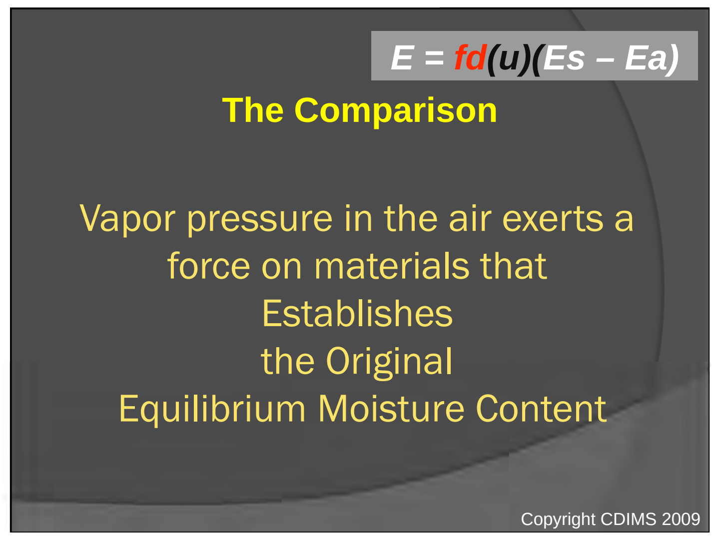


Understanding Complex Materials


Vp pressure differential provides a pressure gradient that begs to Equalize
RH is nowhere to be found here


Vp of water vapor is powerful
1" Hg = 13.57" w.c
3.37 kPa = 13.57" w.c


Vp pressure differential provides a pressure gradient that begs to Equalize
RH is nowhere to be found here


E = fd(u)(Es – Ea)
The Comparison
Vapor pressure in the air exerts a force on materials that Establishes the Original Equilibrium Moisture Content
Copyright CDIMS 2009

E = fd(u)(Es – Ea)

The Comparison

After
Excess water (Vapor) is embedded in wood and complex materials.

E = fd(u)(Es – Ea)

The Comparison

The water and embedded moisture assumes the saturated Vp equal to the temperature of the material

E = fd(u)(Es – Ea)

The Comparison

To allow the moisture to leave the material we must reduce the ambient Vp to allow the moisture to escape in a effort to equalize

E = fd(u)(Es – Ea)

The Comparison

The moisture movement in and through materials can be described as " "Permeance"

The higher the Permeance to faster the excess water will escape

Permeance ASTM D1079

Rate of moisture vapor per unit area at a steady state through a membrane or assembly, (grain/ft^2.hr.in.Hg).

Simply stated, it is the rate that water vapor moves through a roofing or construction material given a specific set of test conditions.

Permeance ASTM D1079

Product	Method	Value, Metric Perms
#15 Asphalt Roofing Felt	E-96 BW	37.7 Perms
#30 Asphalt Roofing Felt	E-96 BW	22.2 Perms
Acrylic Coating (20 mil film, unweathered)	D-1653 BW	45.5 Perms
0.045 mil EPDM	E-96 BW	0.43 Perms
Commercial Underlayment ("Peel and Stick")	E-96 BW	0.05 Perms

Equilibrium Moisture Content

E = fd(u) (Es – Ea)

The water vapor in the air exerts a force to drive to a equilibrium based on material resistance

The restorer must provide a opposite force after upset to return material(s) to equilibrium

MOISTURE REGAIN OF VARIOUS HYGROSCOPIC MATERIALS
Moisture Content Expressed in Per Cent to Dry Weight of the Substance at Various Relative Humidities - Temperature, 75?F? (24?C)

Classification	Material	Description	Relative Humidity - Per Cent									
			10	20	30	40	50	60	70	80	90	Authority
Natural Textile Fibers	Cotton	Sea island-roving	2.5	3.7	4.6	5.5	6.6	7.9	9.5	11.5	14.1	Hartshorn
	Cotton	American-cloth	2.6	3.7	4.4	5.2	5.9	6.8	8.1	10.0	14.3	Schloesing
	Cotton	Absorbent	4.8	9.0	12.5	15.7	18.5	20.8	22.8	24.3	25.8	Fuwa
	Wool	Australian merino-skein	4.7	7.0	8.9	10.8	12.8	14.9	17.2	19.9	23.4	Hartshorn
	Silk	Raw chevennes-skein	3.2	5.5	6.9	8.0	8.9	10.2	11.9	14.3	18.8	Schloesing
	Linen	Table cloth	1.9	2.9	3.6	4.3	5.1	6.1	7.0	8.4	10.2	Atkinson
	Linen	Dry Spun-yarn	3.6	5.4	6.5	7.3	8.1	8.9	9.8	11.2	13.8	Sommer
	Jute	Avg. of several grades	3.1	5.2	6.9	8.5	10.2	12.2	14.4	17.1	20.2	Storch
	Hemp	Manila & sisal-rope	2.7	4.7	6.0	7.2	8.5	9.9	11.6	13.6	15.7	Fuwa
Rayon	Viscous Nitrocellulose Cupramonium	Average skein	4.0	5.7	6.8	7.9	9.2	10.8	12.4	14.2	16.0	Robertson
	Cellulose Acetate	Fiber	0.8	1.1	1.4	1.9	2.4	3.0	3.6	4.3	5.3	Robertson

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Here are Some More

Misc. Organic Materials	Leather	Sole oak-tanned	5.0	8.5	11.2	13.6	16.0	18.3	20.6	24.0	29.2	Phelps
	Catgut	Racquet strings	4.6	7.2	8.6	10.2	12.0	14.3	17.3	19.8	21.7	Fuwa
	Glue	Hide	3.4	4.8	5.8	6.6	7.6	9.0	10.7	11.8	12.5	Fuwa
	Rubber	Solid Tire	0.11	0.21	0.32	0.44	0.54	0.66	0.76	0.88	0.99	Fuwa
	Wood	Timber (average)	3.0	4.4	5.9	7.6	9.3	11.3	14.0	17.5	22.0	Forest P. Lab
	Soap	White	1.9	3.8	5.7	7.6	10.0	12.9	16.1	19.8	23.8	Fuwa
	Tobacco	Cigarette	5.4	8.6	11.0	13.3	16.0	19.5	25.0	33.5	50.0	Ford

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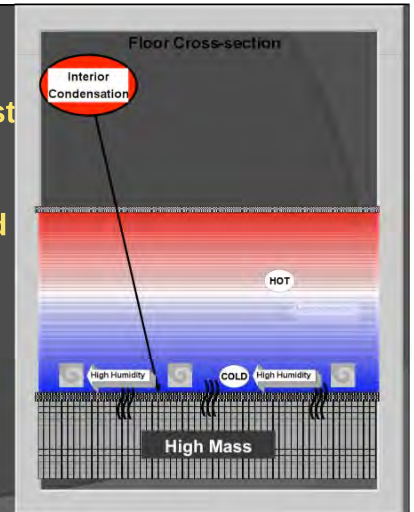
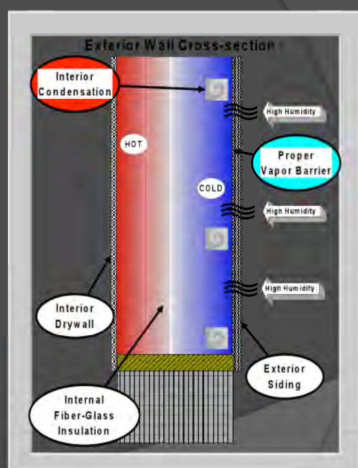
FLOORS
Can be the toughest

Floors can act as a Air Conditioner and Condense Water Vapor on Cold Surfaces



Walls

Interior of Wall can act as a Air Conditioner and Can Condense Water Vapor on Cold Surfaces



Temperature is still important

Air is easy to Heat.. Things are not

The Equalizer for Water Evaporation is Differential Vp

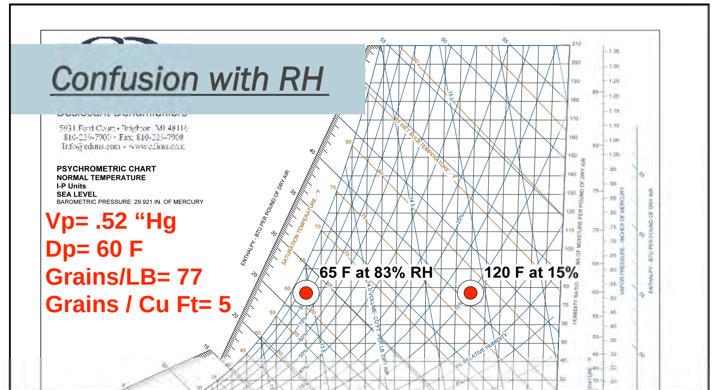
Higher Vp wants to Equalize (Wet)

with

Lower Vp (Dry)

It will use " Hg (kPa) to do it
RH just doesn't cut it…

Confusion with RH



Dry Bulb (°F)	Wet Bulb (°F)	Relative Humidity (%)	Humidity Ratio (gr/lb)	Specific Volume (cu.ft./lb)	Enthalpy (Btu/lb)	Dew Point (°F)	Density (lb/cu.ft.)	Vapor Pressure (in.Hg)	Absolute Humidity (gr/cu.ft.)
120.000	77.953	15.0	77.0	14.866	41.064	59.800	0.0680	0.5182	5.182

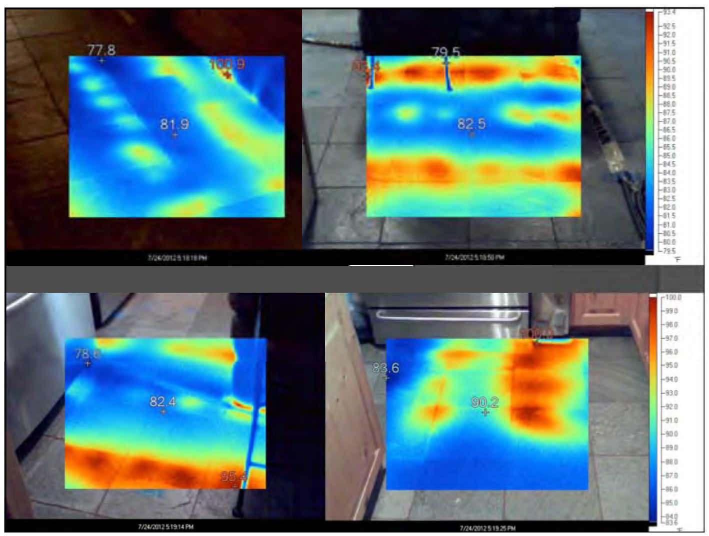
83% RH

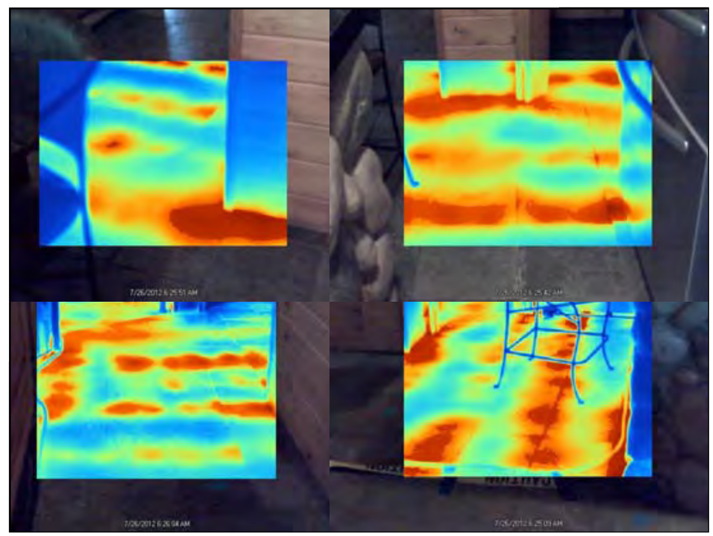
DATA

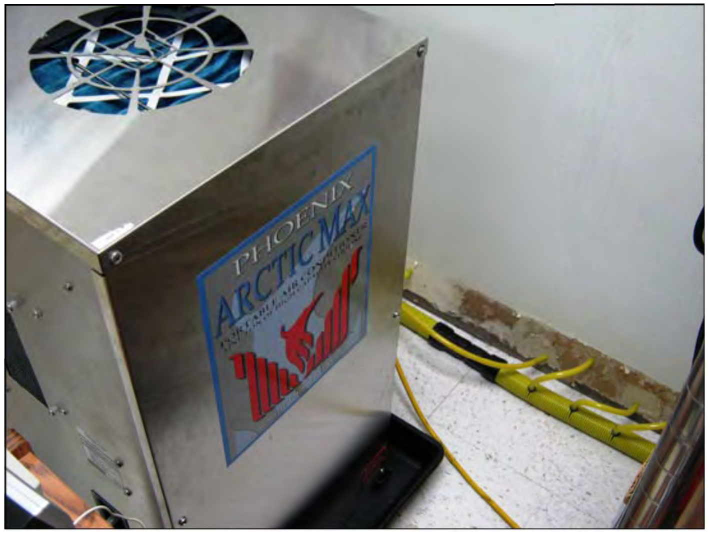
Dry Bulb (°F)	Wet Bulb (°F)	Relative Humidity (%)	Humidity Ratio (gr/lb)	Specific Volume (cu.ft./lb)	Enthalpy (Btu/lb)	Dew Point (°F)	Density (lb/cu.ft.)	Vapor Pressure (in.Hg)	Absolute Humidity (gr/cu.ft.)
65.000	61.661	83.2	77.0	13.456	27.588	59.780	0.0751	0.5178	5.723

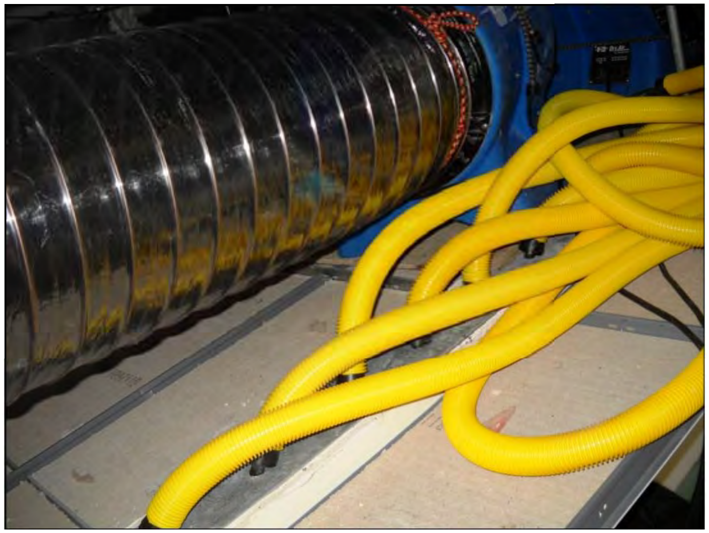
SO YOU HAVE A WET STRUCTURE? TAME IT

Guess what, no *PhD* required to dry it.


77.8
100.9
81.9
79.5
82.5
78.6
82.4
83.6
90.2



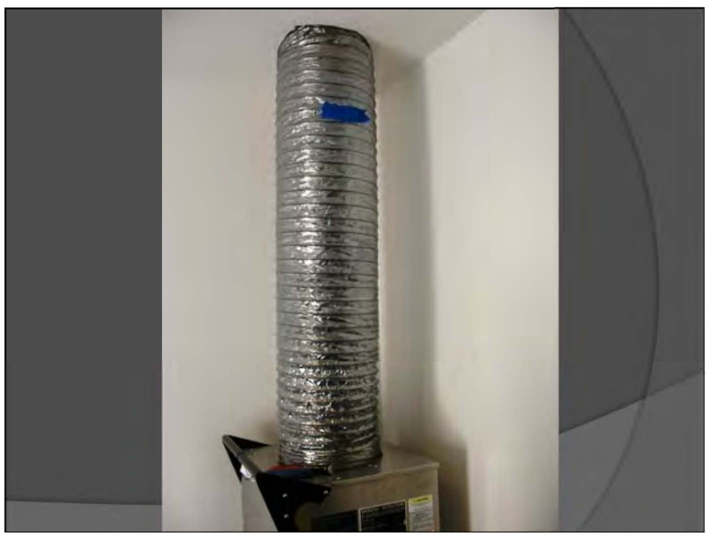

PHOENIX
ARCTIC MAX

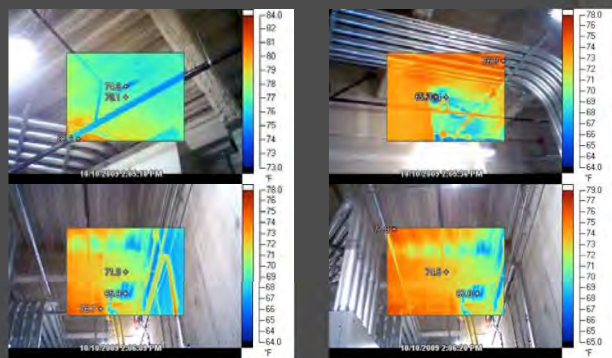



PHOENIX

When Might Heat Not Be Practical?

- Apartment house which required 8,000 sq feet (16,000 cu ft) of attic space to be dried in the winter time with ambient below freezing.
- Heat dissipated in the delivery duct.
- However, the dew point we created stayed the same and reduced the vapor pressure in the airspace and did the drying.
- Would it have dried faster with heat? Yes as evaporation would have been enhanced, but delivery system not practical.



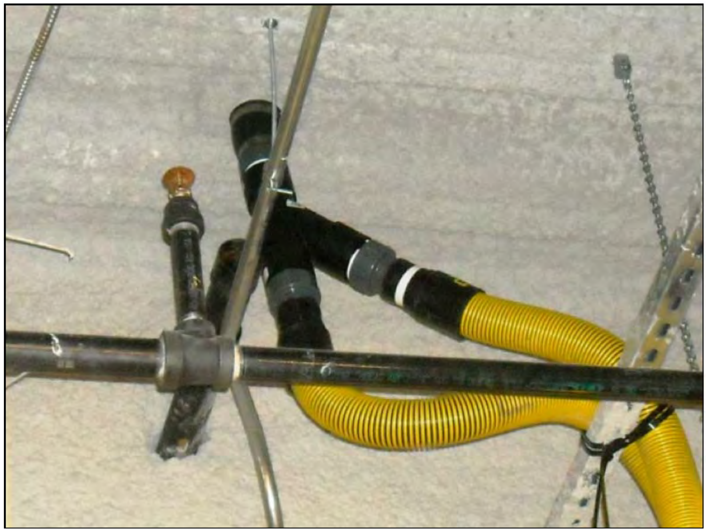


Dehumidification & Interstitial Space Air Movement

- 8 layer flooring system
- Kitchen used every day
- Ultra high security…limited access

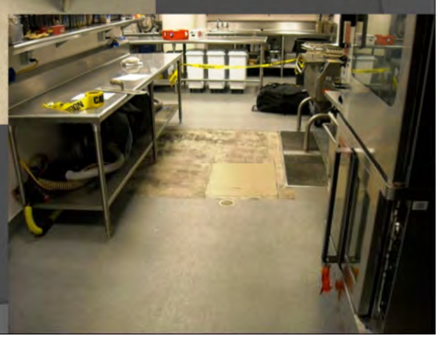
Layers In 1200 Sq Ft Wet Area

- Vinyl flooring with refers & freezers etc.
- Concrete pour
- 12" Styrofoam layer with cutouts for plumbing
- Enka Drain Mat
- Concrete pour
- Membrane
- Steel pan decking
- Spray on fireproofing




DKI
BALES
24 HR EMERGENCY EXTRACTION
800-492-2537
PROMPT
RELIABLE
COURTEOUS
PROFESSIONAL
CAUTION
DO NOT ENTER
CUIDADO
NO ENTRE


Remove bulk water

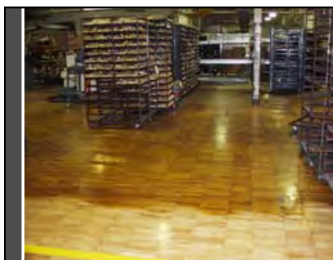


Proving Dry

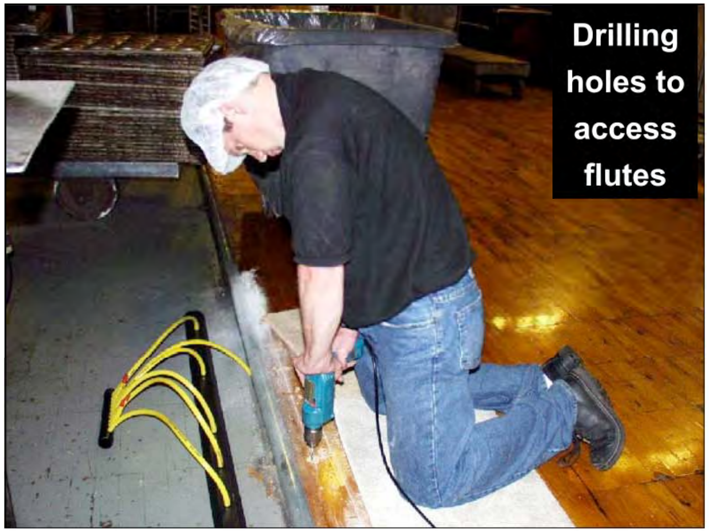
- Let assembly sit without air movement for 24 hours
- Then slightly positively pressurize from kitchen and measure grains coming out of the hole in the lower room
- When grain differential is 0 as measured in the kitchen and the output, the assembly is dry

Another Issue

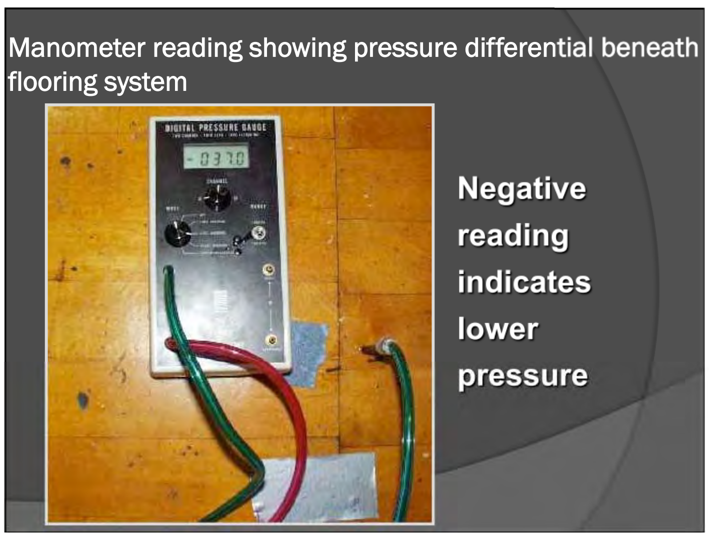
- No discernible air movement as any particulate could contaminate the baked goods.
- Can't dehumidify, can't blow air across flooring (which would not have done any good as the floor was sealed).
- Can't heat up the built environment or materials.



Wide variety of working areas
to contend with


Drilling holes to access flutes


Taping Vents


Manometer reading showing pressure differential beneath flooring system
Negative reading indicates lower pressure


Boards running in different directions
Test hole drilled for testing pressure differential at this point
Moisture Readings


Hoselines had to be nestled against walls out of the walk area

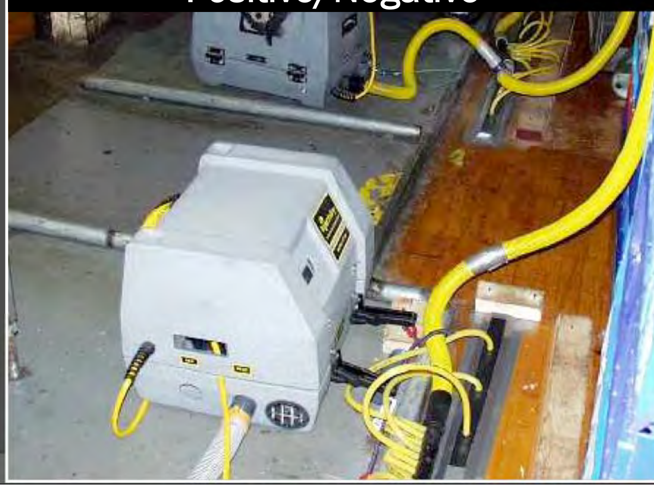

Conveyor Belts located in many different areas


Contaminated air was ducted out of building


Some equipment had to be located overhead to avoid trip hazard

The power of suction pulled newly poured concrete through a studded wall, flooring flutes, and up through drying holes, through hoses and into the blower

Positive/Negative



Answer To Many Wet Dense Structure Problems

- Force air to come to a known location from the wet area…especially at the start.
- Test to ensure pressure differential between built environment and wet interstitial spaces. If negative, ambient air below dew point is drawn across the wet hidden areas, an appropriate equilibrium will slowly occur.
- Materials in buildings are always straining in a dynamic fashion to be in harmony and in equilibrium with atmospheres.

Needed

- Lower vapor pressure air must be introduced into each area including medium to small interstitial spaces.
- Low permeability and low capillarity will greatly slow the drying process.
- Out of sight out of mind in too many cases.

Wait A Minute I Have The Answer

- A house and contents are simply analogous to a clothes dryer and contents, therefore **all I need is heat** *(restorer with a heat ox in the contest)*

Wait A Minute I Have The Answer

- **Air movement is all I need**…just move it fast enough across the surfaces. No dehumidifiers required, just open the window you idiot overcharging SOB. It's summer.
- You call them "airmovers" and charge twice what you should. *(adjuster who* ***knows*** *all restorers overcharge and overcomplicate)*

Wait A Minute I Have The Answer

- **Dehumidification is all that is needed**, after all, moisture will travel up an airstream to reach a lower vapor pressure.
  - Refrigerants are all you need. Desiccants are too expensive. *(restorer who does not understand desiccants)*
  - Desiccant technology rules as I can get a -40°f dew point. *(restorer who always wants to hit with a sledge hammer)*

In Reality

- Just focusing on one metric (relative humidity) can be misleading
- Since the building is so wildly out of whack with materials normally at e.g. 8% moisture content…now at 20%, simply working with Rh is not enough
- After all, we could have 40% Rh and a temp of 120f giving us a dew point of 89f. Any parts of the structure at or below 89f will be condensing moisture out of the atmosphere.

Predictability

- The insurance industry and those who audit repair costs are looking for specific predictability…in a way that is not dissimilar to the auto industry trying to come up with standardized costs for the right front quarter panel replacement on a 2011 Toyota Camry. Structures do not dry as predictably as contractors would like. If even lumber dried predictably, there would be no need for moisture sensor placed strategically through the stacks in multiple locations.

Please

- "Don't confuse me with the facts. I've got a closed mind." These words were famously uttered by Rep. Earl Landgrebe (R-IN), a Nixon partisan to the bitter end, at the Watergate hearings.
- Restoration Contractors sometimes engage in similar specious logic… "all I need is"….and where is Chevy Chase to finish this line from ***The Jerk***?

Surely There Is "A" Way To Dry

- Many want simplistic answers to complex problems
- Many want to know the answer to "how many days", "how many dehumidifiers" etc.
- Then there is the over complexity that can be introduced on straightforward jobs.

What Seems To Work?

- All moist or wet materials and spaces large and small need to be exposed to lower vapor pressure moving air at a temperature which is above the dew point of the materials exposed to this moving medium. The greater the differential the steeper the drying gradient.
- Not rocket science.