DEMYSTIFYING SILICA GEL FOR EFFECTIVE MICROCLIMATES

JANUARY 22, 2019

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A.M. ART CONSERVATION

OUTLINE

- OVERVIEW OF AGENTS OF DETERIORATION, TYPES OF DAMAGE & THE NEED FOR ENVIRONMENTAL CONTROL
- WHAT IS A MICROCLIMATE?
- HOW DO WE CONTROL MICROCLIMATES?
- WHAT IS SILICA GEL?
- USING SILICA GEL EFFECTIVELY
  - CALCULATING AMOUNTS
  - PLACEMENT
  - MONITORING
  - RECONDITIONING
  - STORING

REVIEW OF ENVIRONMENTAL ISSUES

Types of Deterioration

Chemical

Mechanical

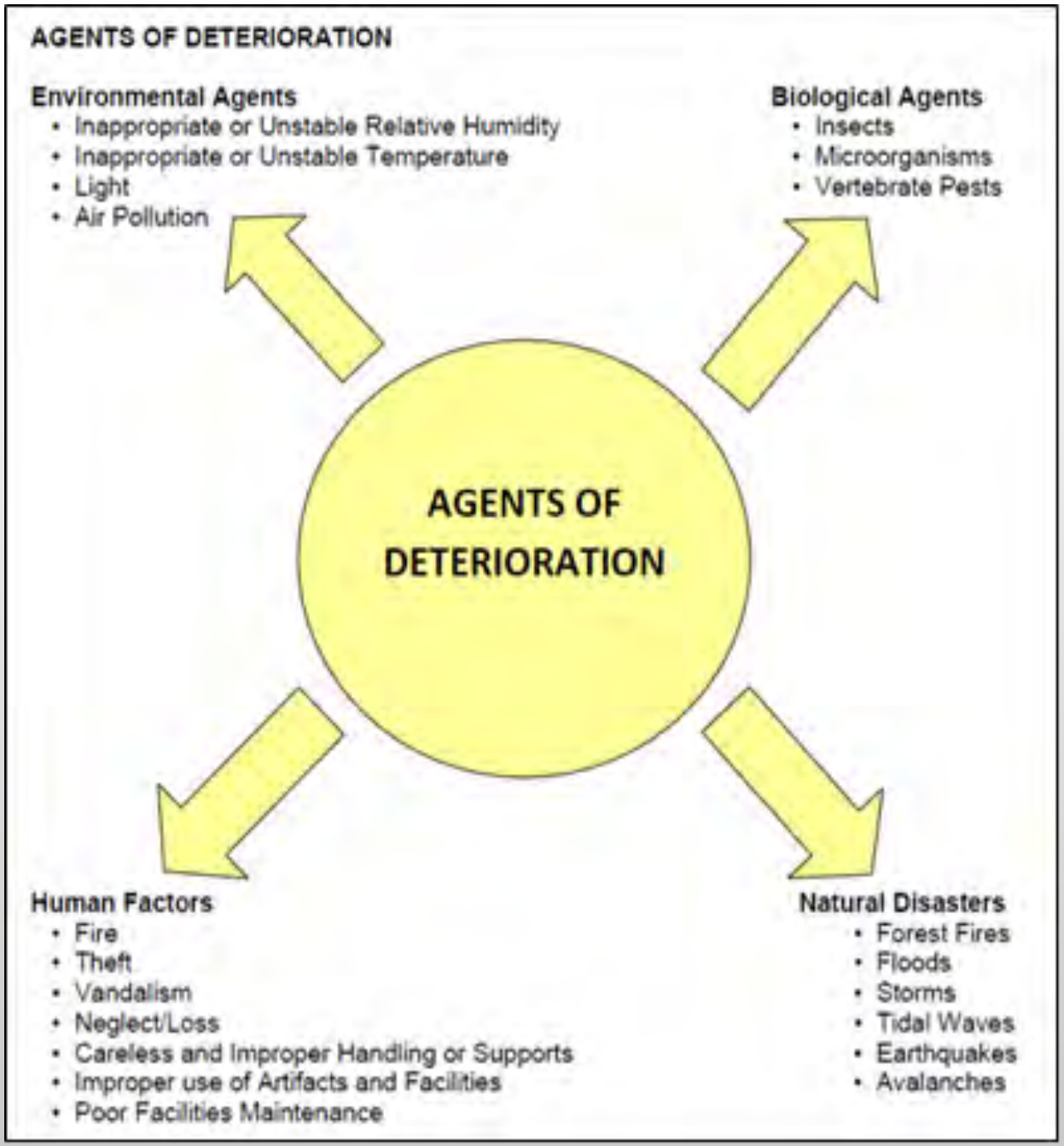
Biological

http://protectheritage.com/Lisbon2011/wp-content/uploads/2011/12/Linden-frinal-corrected-reduced-file-size.pdf

Agents of Deterioration

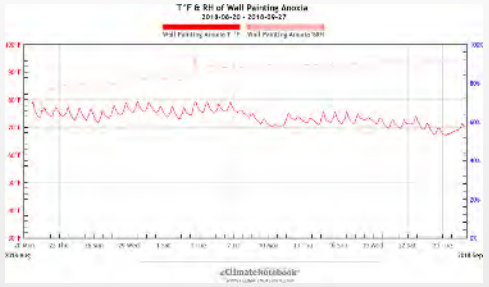
Environmental Agents

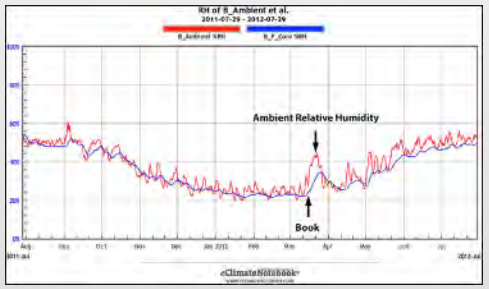
- Incorrect relative humidity (RH)
- Incorrect temperature
- Light
- Pollutants

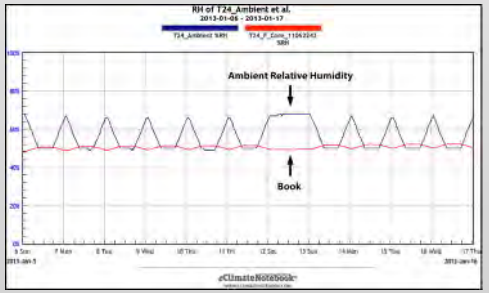


https://www.canada.ca/en/conservation-institute/services/agents-deterioration.html

Incorrect Relative Humidity







1. RH too high
2. RH too low
3. Fluctuating RH
4. RH above or below an object specific critical value

https://www.canada.ca/en/conservation-institute/services/agents-deterioration/humidity.html#tft2a

U.S. Collections Are Exposed to Hazards

The Heritage Health Index found that collections are at risk of damage because of improper environmental conditions and storage.

An improper environment can cause irreparable damage.

26% of collecting institutions have no environmental controls to protect their collections from damaging effects of temperature, humidity, and light.

59% of collecting institutions have had their collections damaged by light.

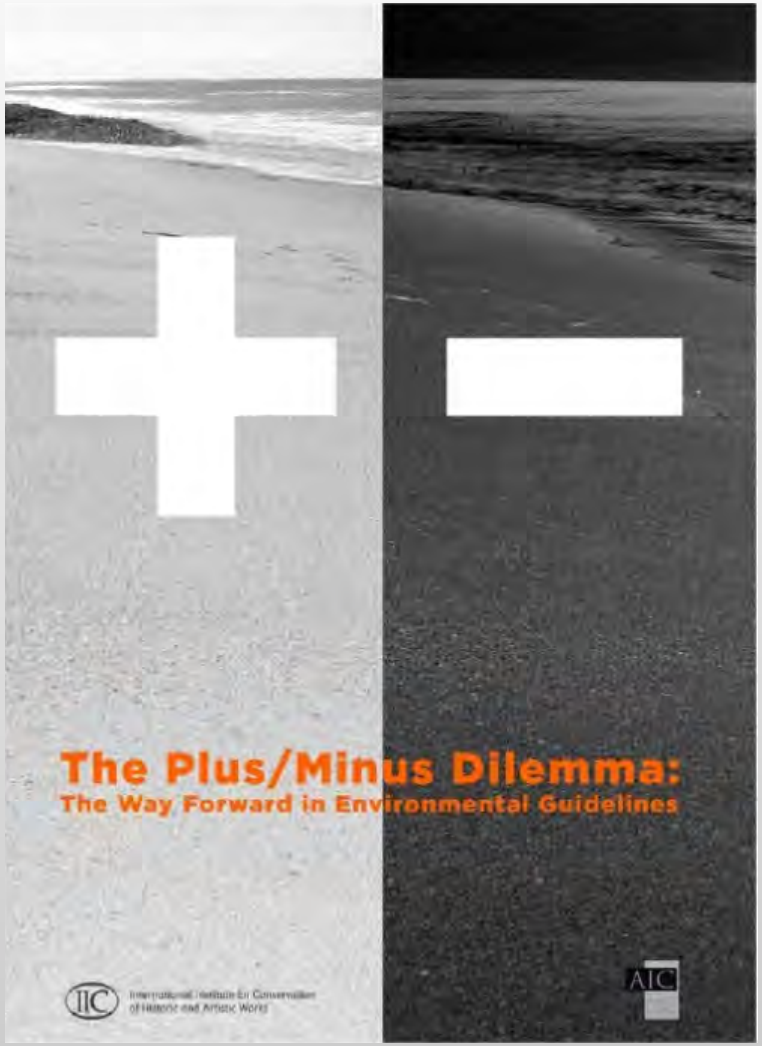
53% of collecting institutions have had their collections damaged by moisture.

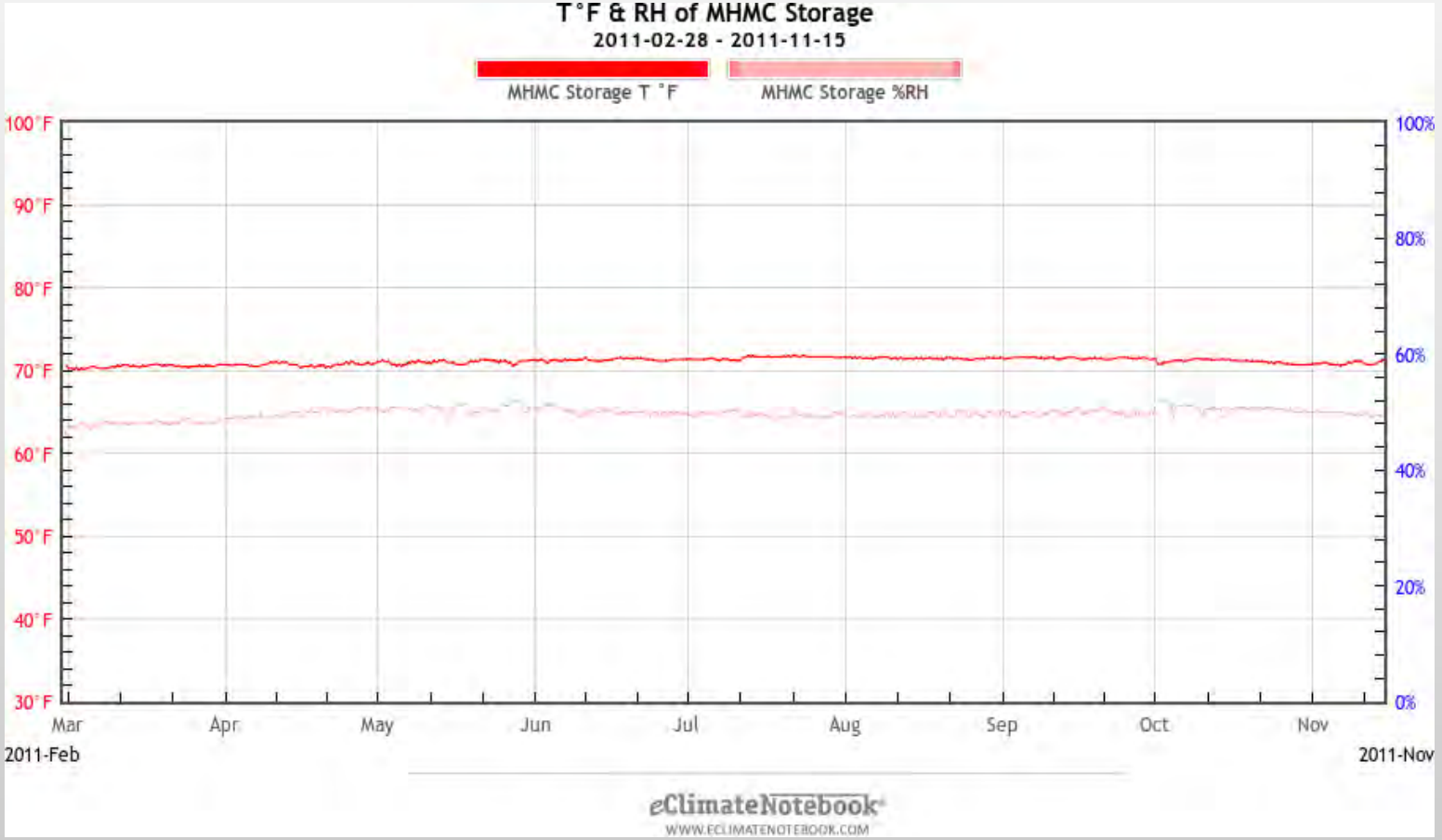
A Public Trust at Risk:
The Heritage Health Index Report on the State of America's Collections

A Project of Heritage Preservation and the Institute of Museum and Library Services

http://www.conservation-us.org/docs/default-source/hhi/hhisummary.pdf?sfvrsn=2

The 70/50 Debate





https://www.academia.edu/1500445/2010._The_Plus_Minus_Dilemma_A_Way_Forward_in_Environmental_Guidelines

MICROCLIMATES

What can we control?

https://www.canada.ca/en/conservation-institute/services/agents-deterioration/humidity.html

What is a microclimate?

Dictionary

microclimate

mi·cro·cli·mate

/ˈmīkrōˌklīmət/

noun

noun: **microclimate**; plural noun: **microclimates**; noun: **micro-climate**; plural noun: **micro-climates**

the climate of a very small or restricted area, especially when this differs from the climate of the surrounding area.

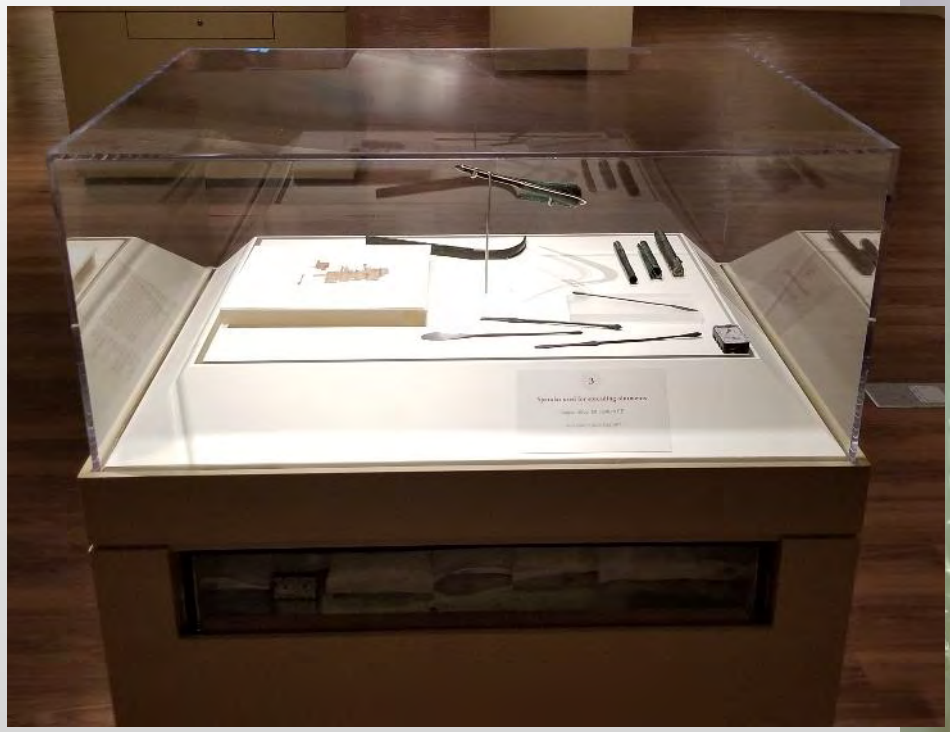
What is a microclimate?

© Government of Canada, Canadian Conservation Institute. CCI 126258-0005
Figure 13. These iron objects are packed for dry storage in a food container with silica gel and an RH indicator card.

Images (L to R):
https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/archaeological-collections.html
http://vikingmetal.com/case-studies/custom-cabinets-art-museum/

CONTROLLING MICROCLIMATES

Active versus Passive



Images (L to R):

1. Active control unit on the back of a vitrine - https://www.collectioncare.org/museum-microclimates-line-course
2. Xergy's Xumidor unit controlling the environment in a vitrine
3. Silica gel chamber under a vitrine displaying archaeological metals
4. Oxygen absorber and desiccant RP System sachets used by conservator Ellen Carrlee for post-treatment control https://ellencarrlee.wordpress.com/2013/06/13/shipwreck-doll/

Active versus Passive: How do I choose?

- Humidity level and range desired
- Ambient conditions
- Enclosure size
- Enclosure materials
- Leakage rate
- Exhibition duration
- Composition and size of the artifact
- Resources

Active versus Passive: How do I choose?

Active

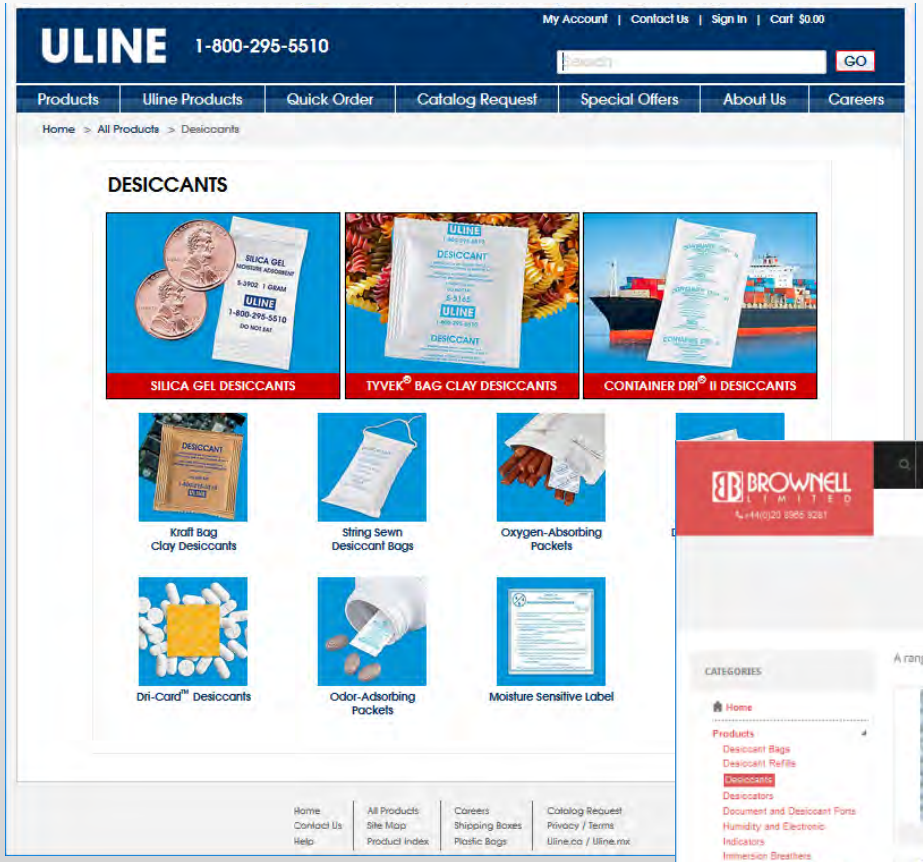
- ✓Large and/or leaky enclosures
- ✓Substantial difference in the desired climate from the ambient
- ✓Long-term need
- ✓Power source is available
- ✓Higher level of resources

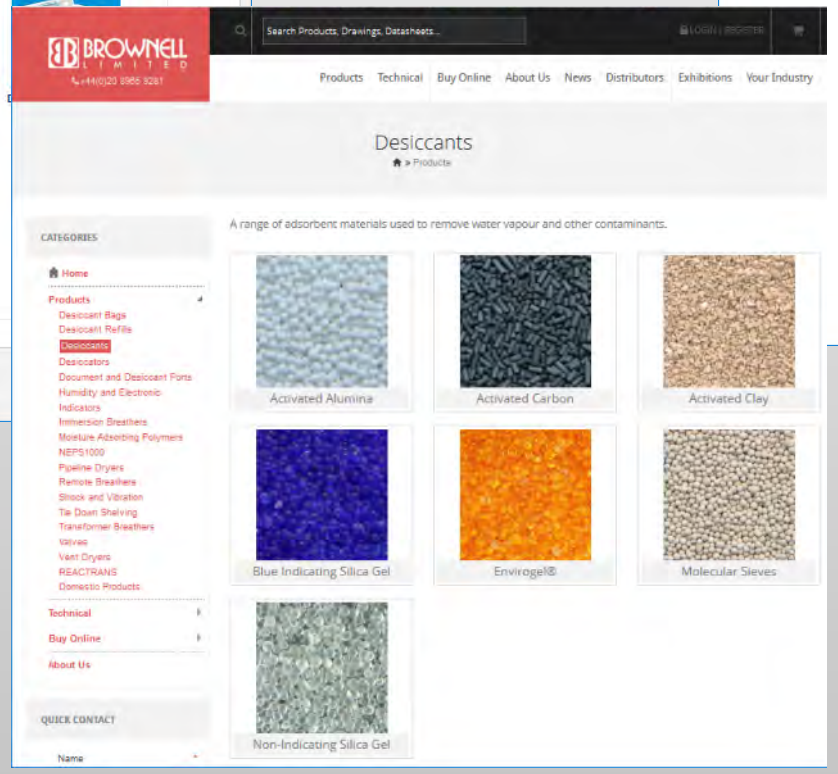
Passive

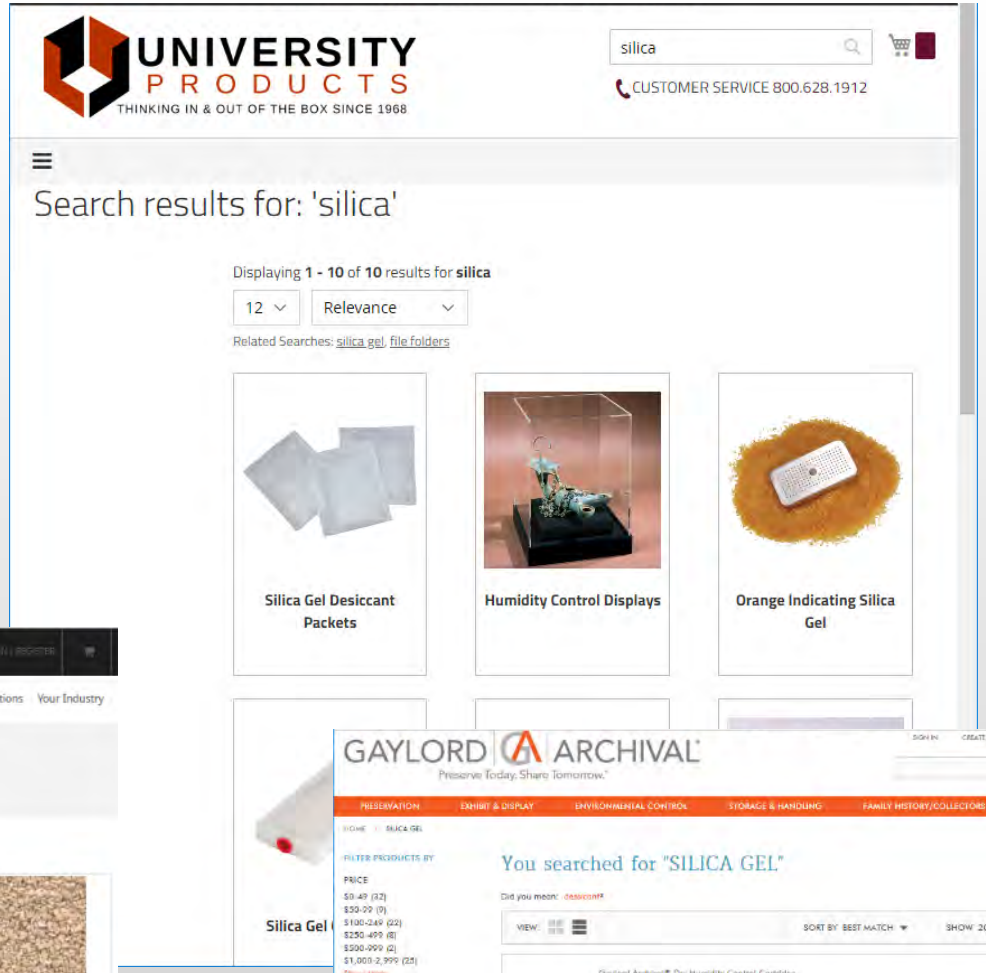
- ✓Small and/or tight enclosures
- ✓Moderate or dry environment
- ✓Buffering versus changing the environment
- ✓Short or long-term needs
- ✓No power source
- ✓Limited resources

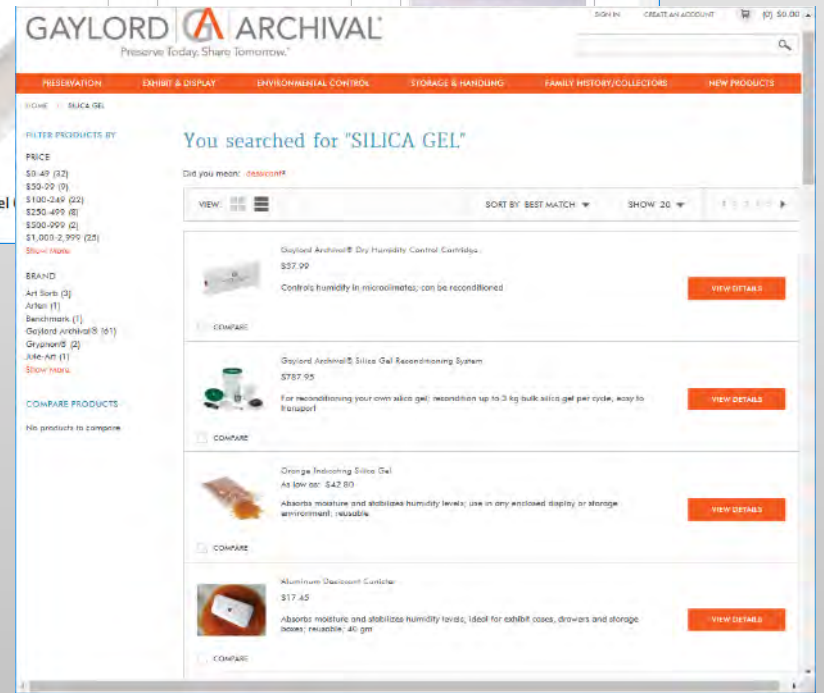
OVERVIEW OF SORBENTS

Materials for Passive Control









Materials for Passive Control - Salts

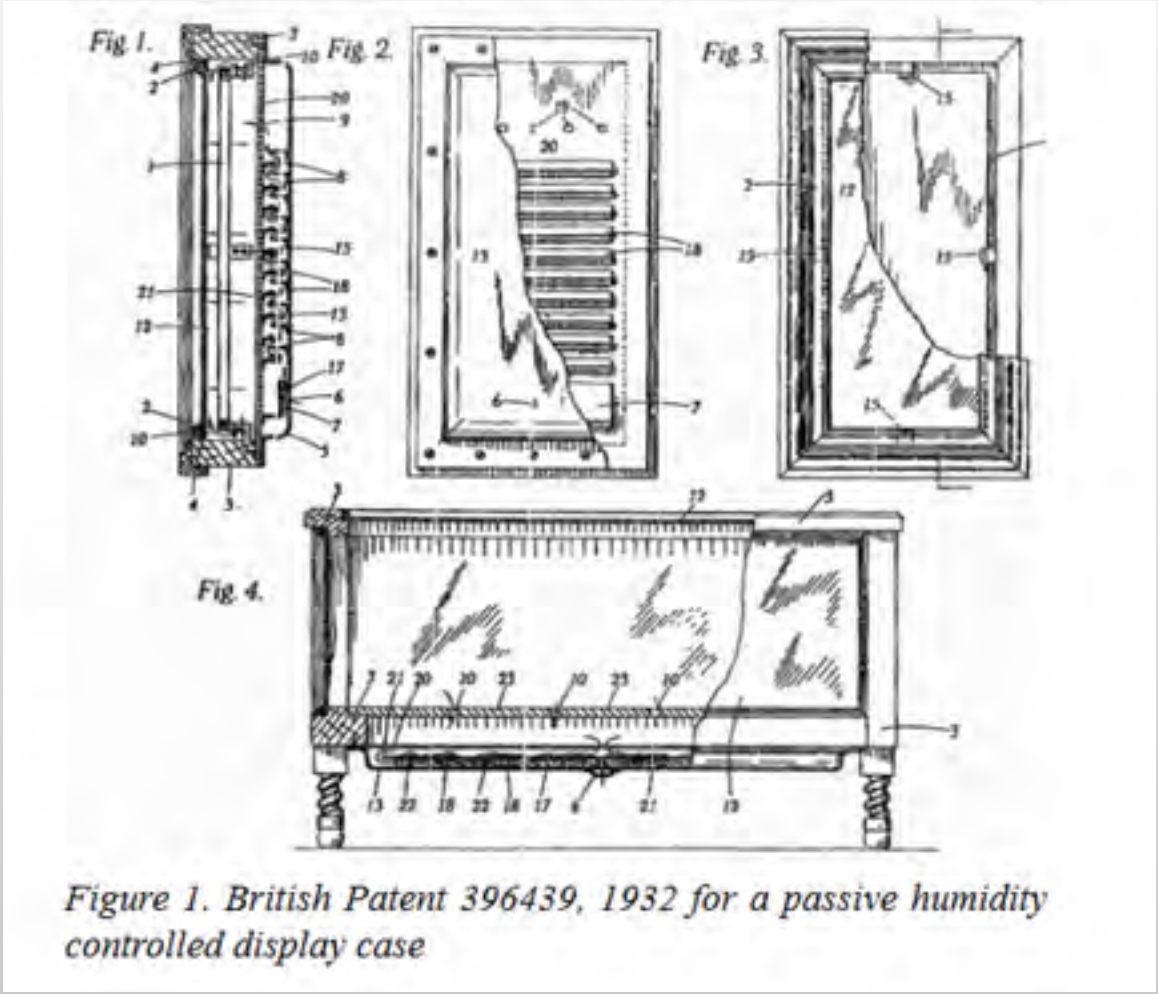
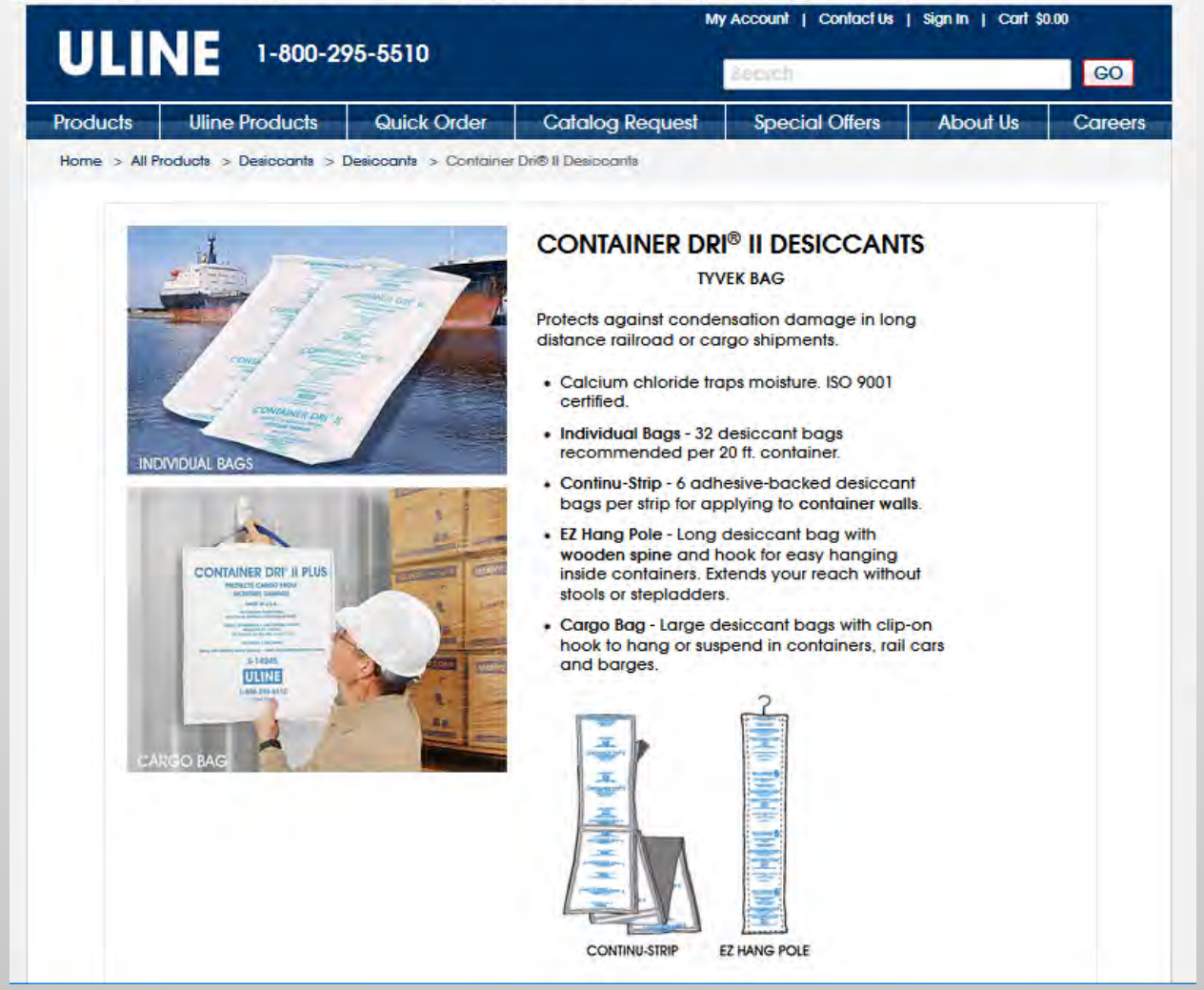


Figure 1. British Patent 396439, 1932 for a passive humidity controlled display case

Relative Humidity (%RH)			
Temperature °C	Lithium Chloride	Potassium Acetate	Magnesium Chloride
0	11.23 ± 0.54		33.66 ± 0.33
5	11.26 ± 0.47		33.60 ± 0.28
10	11.29 ± 0.41	23.28 ± 0.53	33.47 ± 0.24
15	11.30 ± 0.35	23.40 ± 0.32	33.30 ± 0.21
20	11.31 ± 0.31	23.11 ± 0.25	33.07 ± 0.18
25	11.30 ± 0.27	22.51 ± 0.32	32.78 ± 0.16
30	11.28 ± 0.24	21.61 ± 0.53	32.44 ± 0.14
35	11.25 ± 0.22		32.05 ± 0.13
40	11.21 ± 0.21		31.60 ± 0.13
45	11.16 ± 0.21		31.10 ± 0.13
50	11.10 ± 0.22		30.54 ± 0.13
55	11.03 ± 0.23		29.93 ± 0.16
60	10.95 ± 0.26		29.26 ± 0.18
65	10.86 ± 0.29		28.54 ± 0.21
70	10.75 ± 0.33		27.77 ± 0.25
75	10.64 ± 0.38		26.94 ± 0.29
80	10.51 ± 0.44		26.05 ± 0.34
85	10.38 ± 0.51		25.11 ± 0.39
90	10.23 ± 0.59		24.12 ± 0.46
95	10.07 ± 0.67		23.07 ± 0.52
100	9.90 ± 0.77		21.97 ± 0.60

https://www.conservationphysics.org/mm/shiner/shiner.pdf

Materials for Passive Control - Salts



Materials for Passive Control – Activated clays

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All bags meet mil spec. MIL-D-3464E Type I and II. QPL certified. ISO 9001

TYVEK® BAG CLAY DESICCANTS - 5 GALLON PAILS

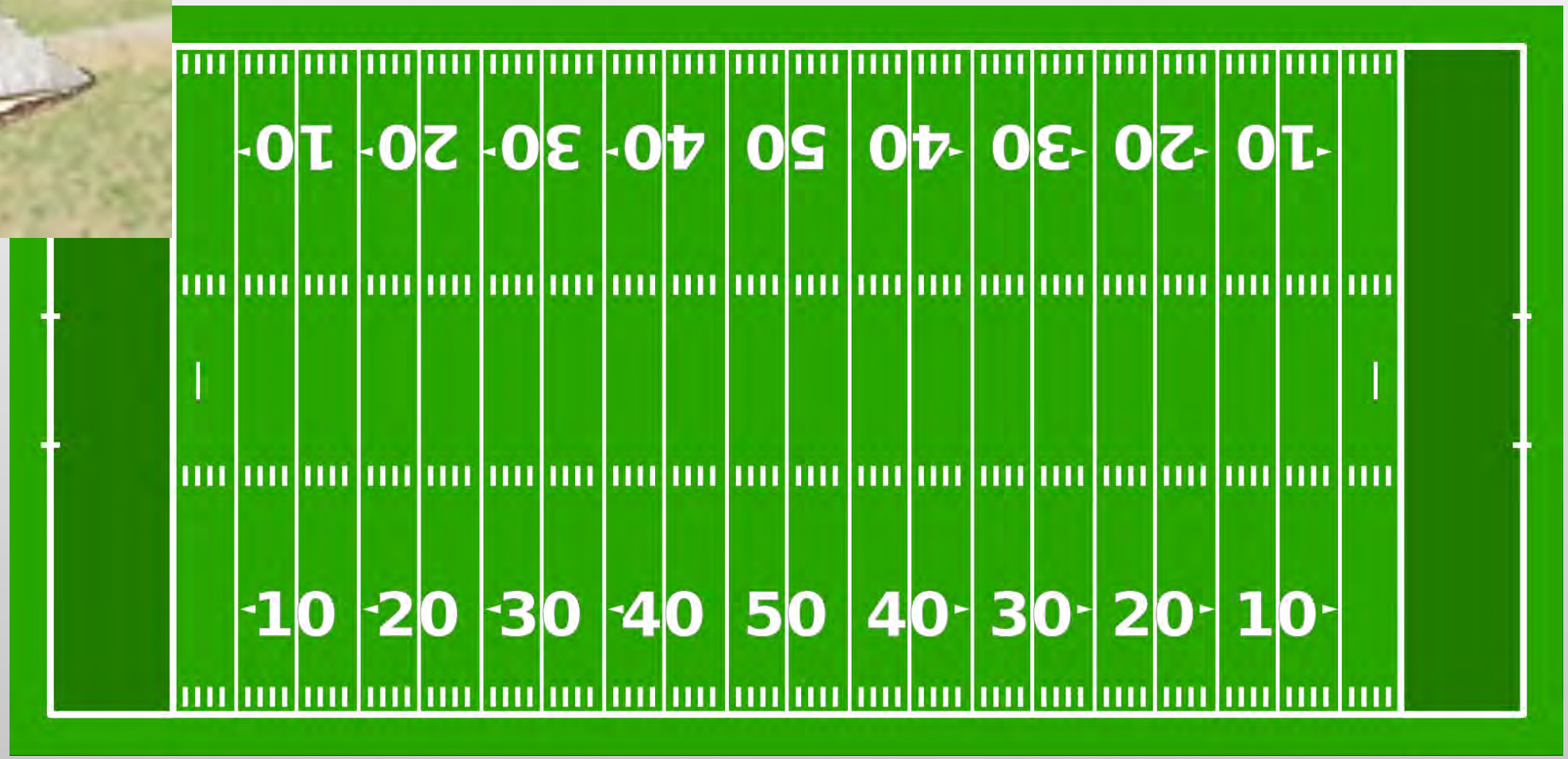
MODEL NO.	UNIT SIZE	BAG DIMENSIONS	PROTECTS CU. FT.	BAGS/ CONTAINER	LBS./ CONTAINER	PRICE PER CONTA 1	2		
S-5163	1/6	1 x 2 1/2 x 1/4"	.14	1,200	24	$101	$95		
S-5164	1/3	1 x 3 1/2 x 1/4"	.28	700	25	91	85		
S-5165	1/2	3 x 3 x 1/4"	.42	550	27	104	98		
S-5166	1	3 x 4 x 1/4"	.83	300	27	83	78	73	1 ADD
S-5167	2	3 x 6 x 3/8"	1.67	150	27	69	65	61	1 ADD

SILICA GEL - THE NITTY GRITTY

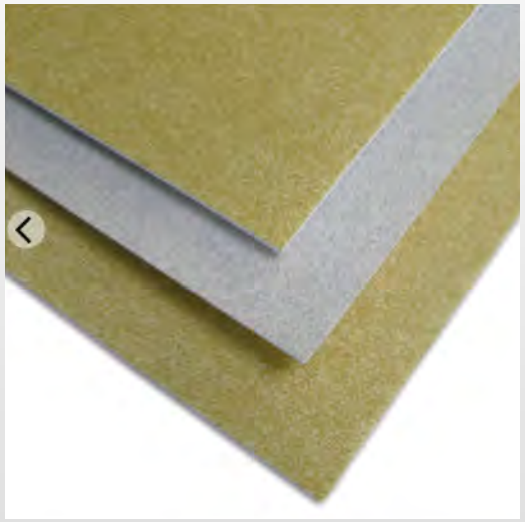
Materials for Passive Control – Silica Gel

https://commons.wikimedia.org/wiki/File:Silica_gel_pb092529.jpg

Materials for Passive Control – Silica Gel



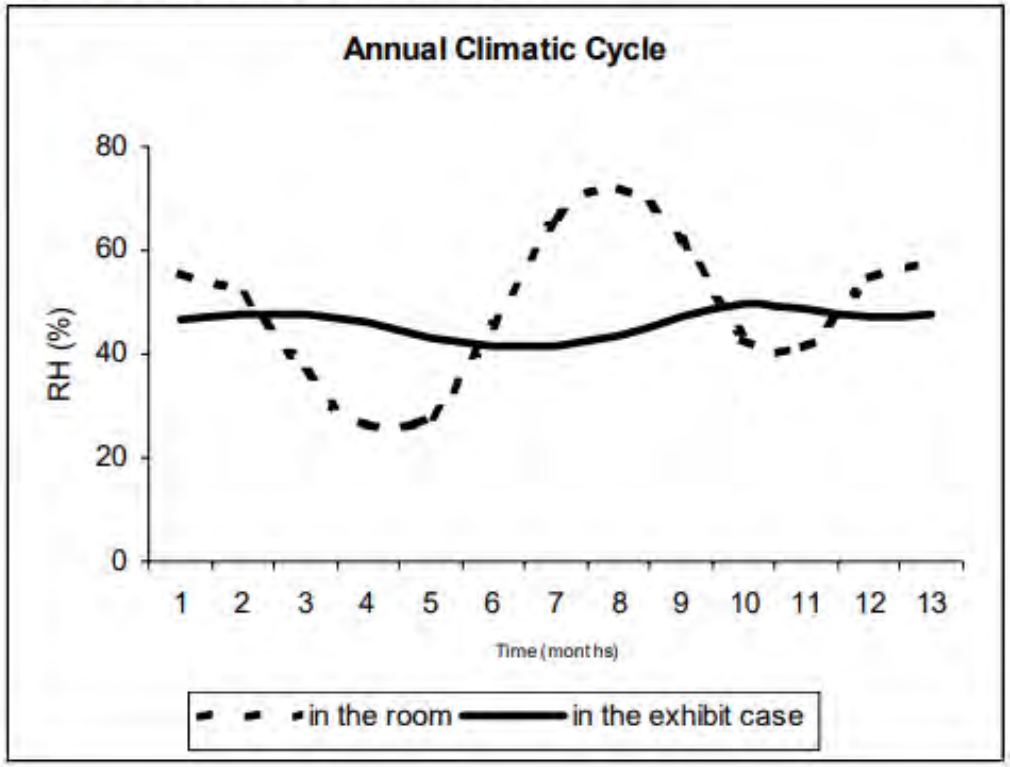
Silica Gel Format & Types

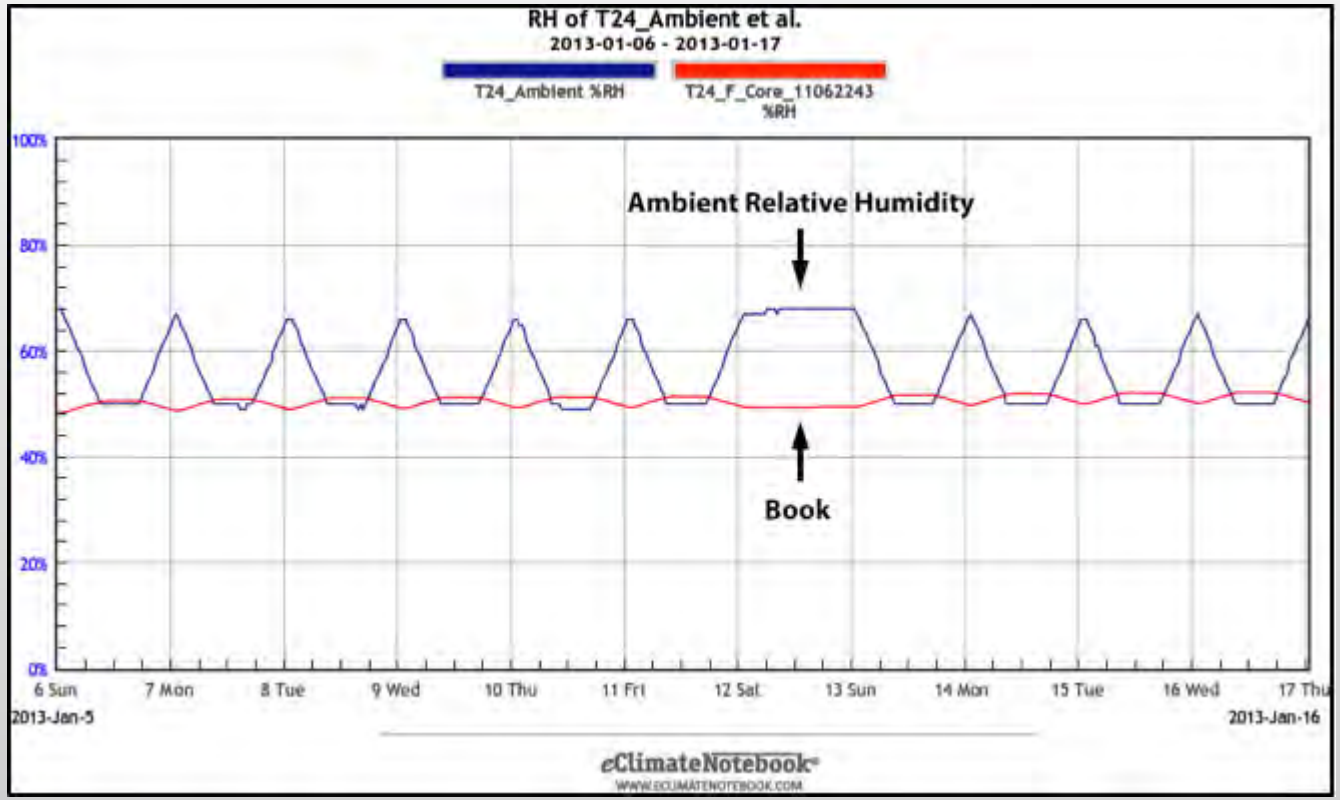


Gel cartridges can be easily emptied and re-filled for reconditioning

Buffering

Figure 2. Annual Climatic Cycle



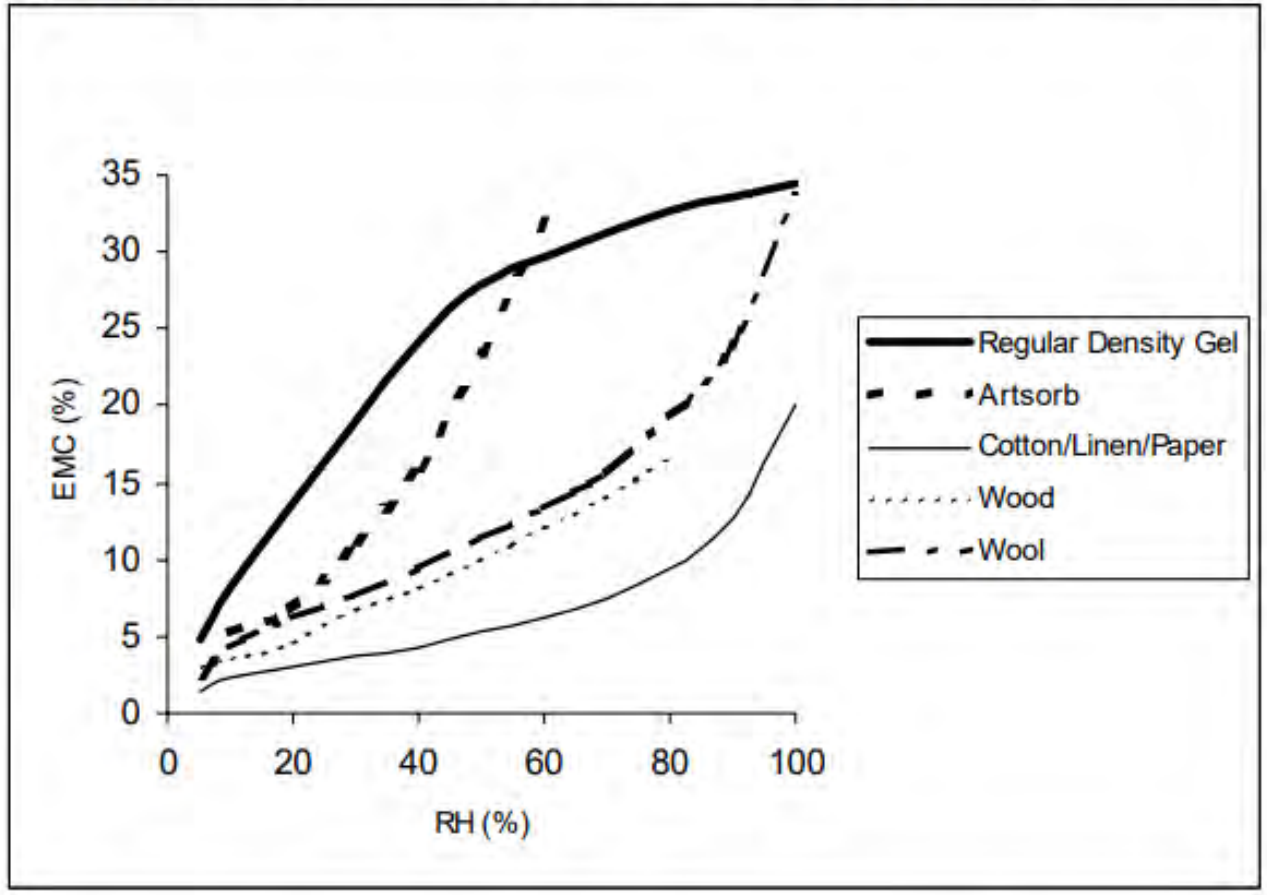


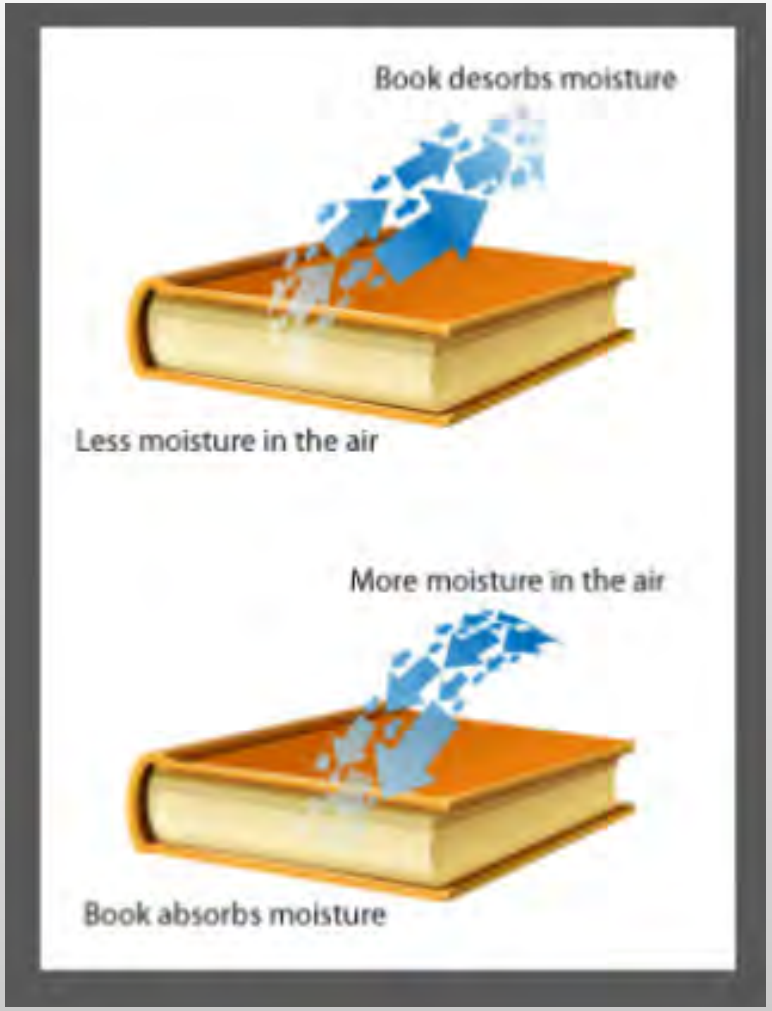
L: Weintraub 2002, p. 2

R: https://www.imagepermanenceinstitute.org/resources/newsletter-archive/v20/ipi-research-equilibration

Equilibrium Moisture Content

Figure 1. Equilibrium Moisture Content / Relative Humidity Isotherm





L: Weintraub, 2002, p. 2

R:

Buffering Capacity – M Value

- M value - the amount of water (in grams) that is gained or lost by 1 kilogram of silica gel for each 1% change in RH.

- Variables affecting M include:
  - The point along the EMC/RH isotherm at which it is measured.
  - The magnitude of the RH range used to determine M.
  - Whether it is measured along the adsorption or desorption isotherm.
  - Hysteresis

Weintraub, 2002 p.4

What the @$*#% is Hysteresis?!

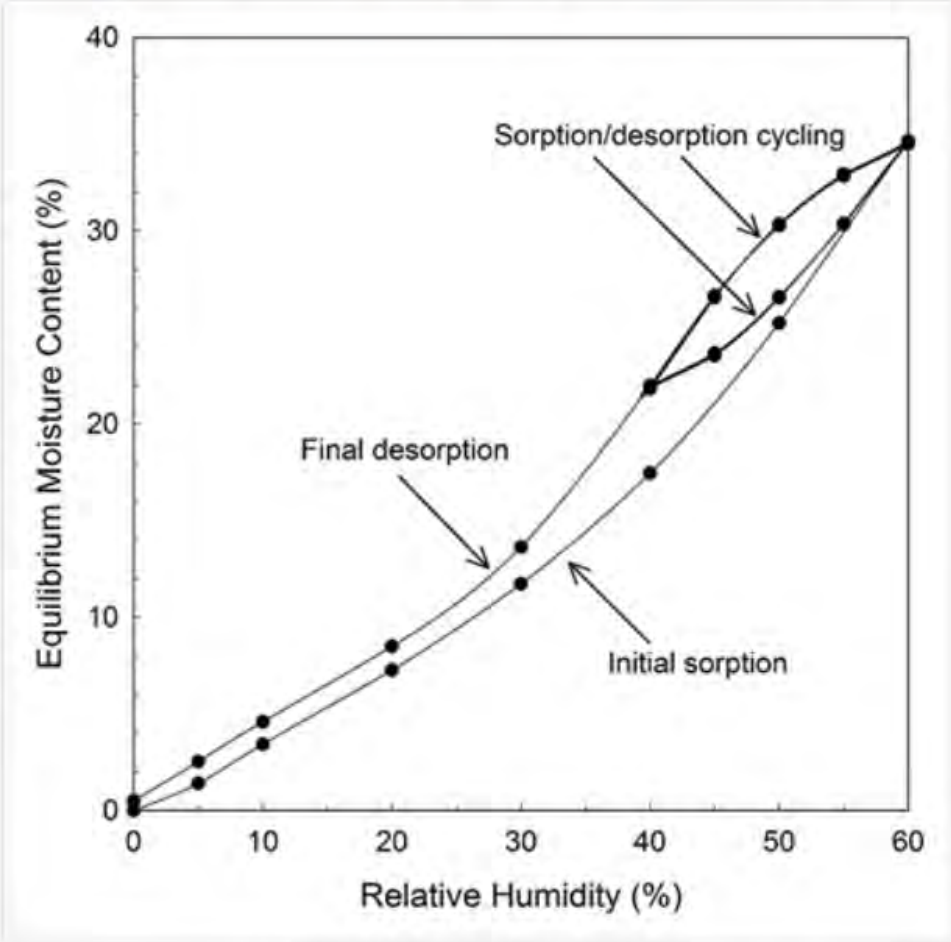


Figure 2. EMC/RH isotherm curves of a sorbent sample with four sorption–desorption cycles between 40% and 60% RH at 20°C.

Buffering Capacity – M_H Value

- Since the M value can change based on whether the gel is adsorbing or desorbing moisture (i.e.hysteresis), we can use M_H value to take this into account.
- M_H value - the **average** amount of water (in grams) that is gained or lost by 1 kilogram of silica gel for each 1% change in RH.
- The ($_H$) designates that hysteresis is accounted for within the specified RH range.
- A higher M_H value indicates a higher buffering capacity.

Weintraub, 2002 p.4

Buffering Capacity of Different Gels

- **A-type** - Good moisture adsorption capacity between 0-50% RH. Above 50% RH, the capacity to adsorb moisture diminishes.
- **B-type and C-type** - Low moisture adsorption capacities below 70% RH and are not appropriate for humidity buffering applications below 70% RH.
- **High-Performance Silica Gels** – Special gels with good buffering characteristics between 0-70% RH. Examples include RHapid Gel, ArtSorb and PROSorb.

Buffering Capacity – HP versus RD

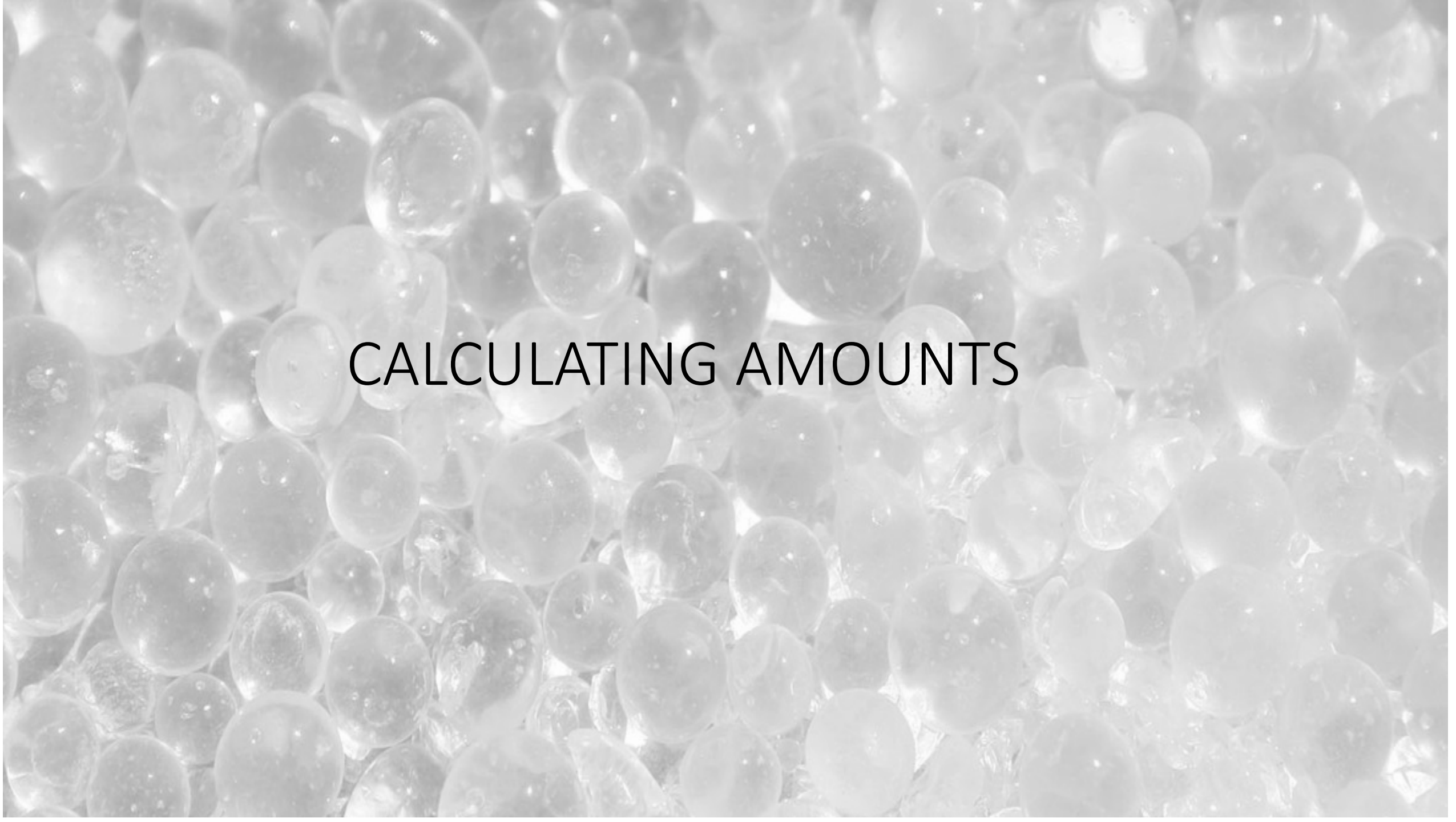
Table 1: specific moisture reservoir (g/kg for a 1% RH change) at 20°C *

Moisture sorbent	M_H 50 ± 10% RH around 50%	M 20 → 30% Keep RH low	M 60 → 50% Keep RH high
RHapid Gel	6.11 ± 2.16	4.48 ± 0.42	4.38 ± 1.40
PROSorb	5.42 ± 1.32	4.37 ± 0.10	4.25 ± 0.38
Art-Sorb	4.04 ± 0.80	2.84 ± 0.47	4.18 ± 0.49
Regular silica gel (clear, type A)	1.93 ± 0.44	5.48 ± 0.40	1.47 ± 0.16
Orange silica gel	1.16 ± 0.26	4.92 ± 0.59	0.94 ± 0.14
Bentonite clay (Desi Pak)	1.19 ± 0.07	2.25 ± 0.03	1.11 ± 0.02
Molecular sieves 4A (zeolite)	0.33 ± 0.02	0.47 ± 0.04	0.31 ± 0.01

Jean Tétreault and Paul Bégin, 2018
https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/technical-bulletins/silica-

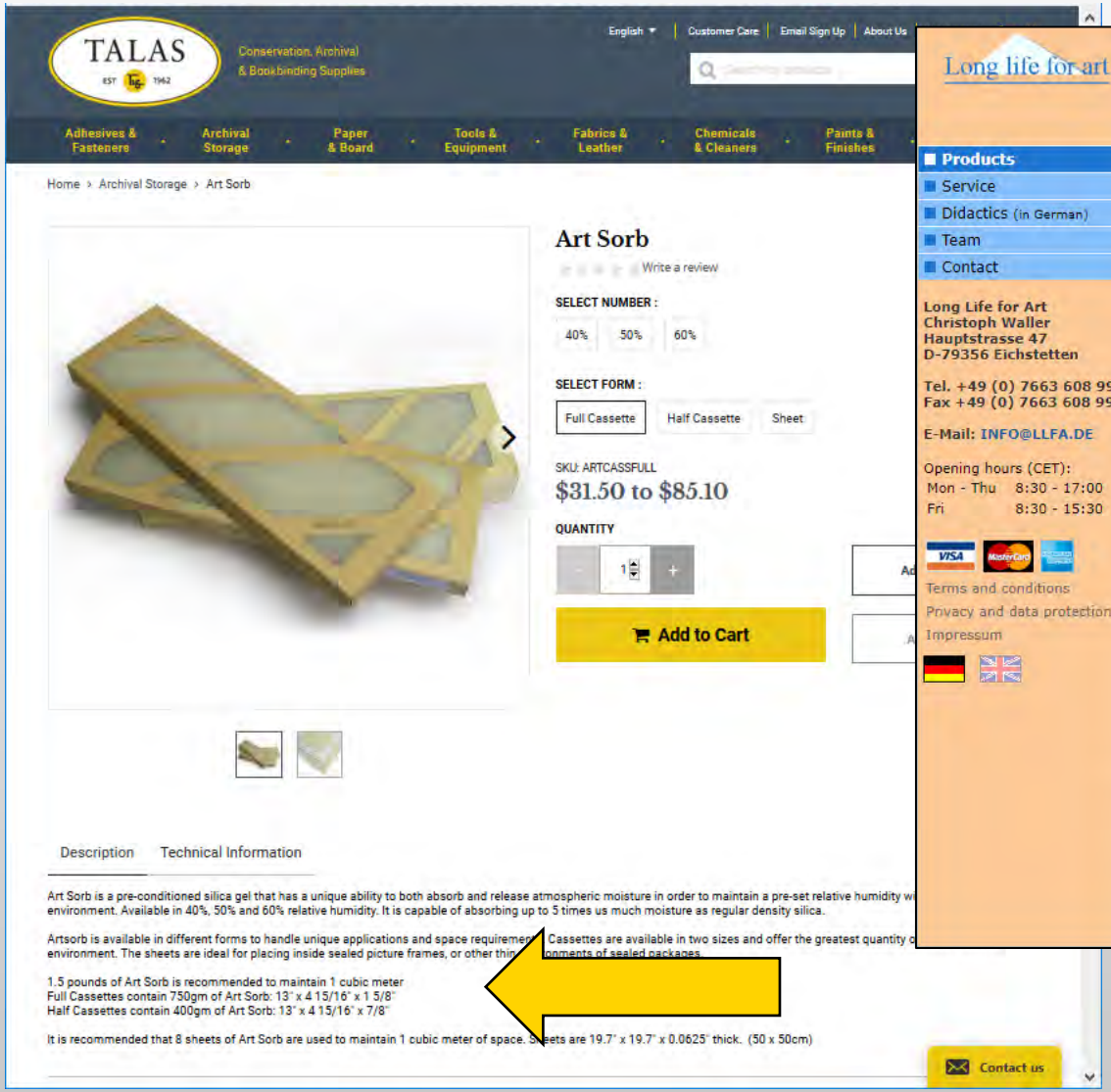
Buffering Capacity – M_H for A-Type Silica Gel

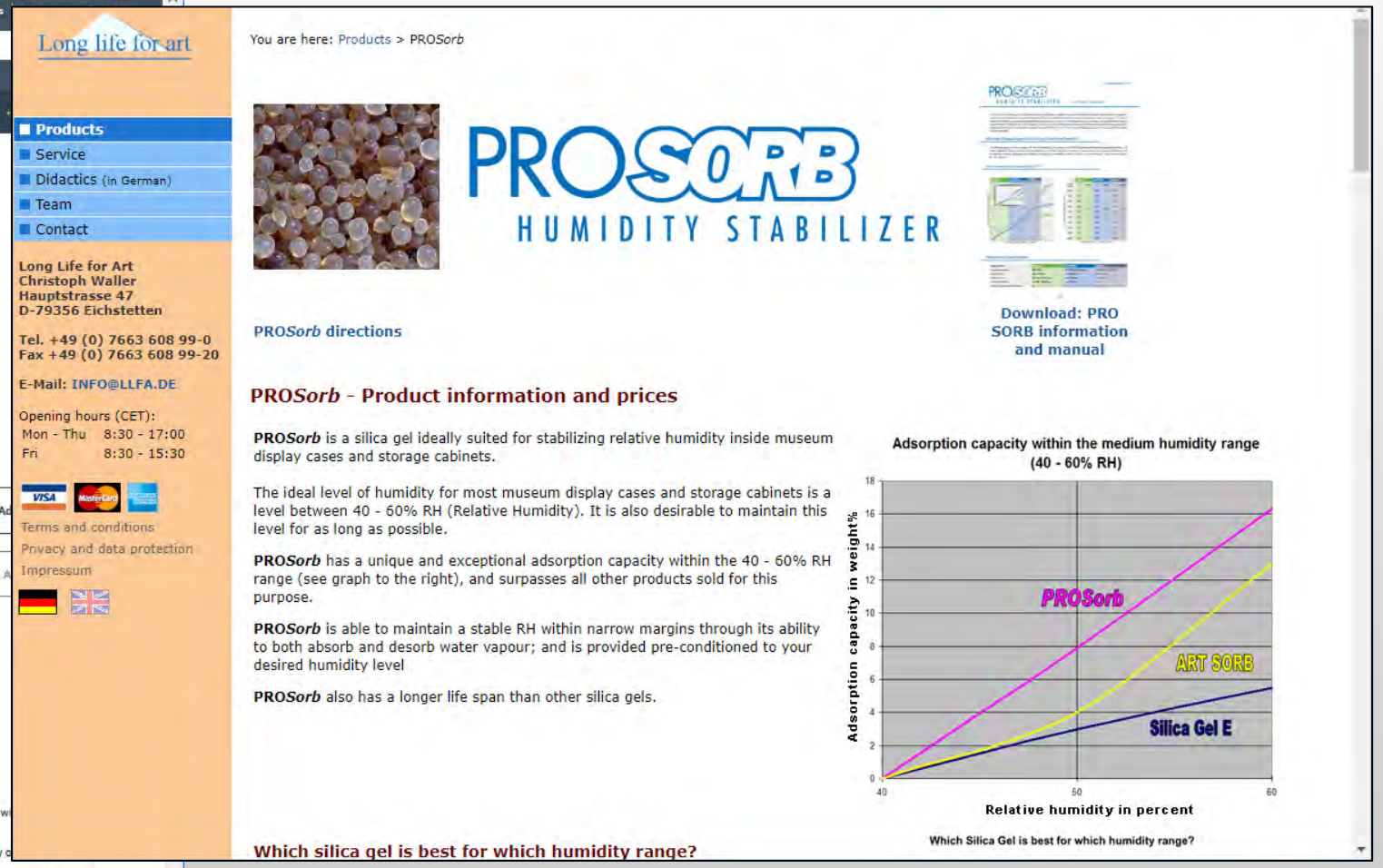
RH Range	Below 45%	40-50%	45-55%	50-60%	Above 60%
M_H	6.0→5.0	3.5	2.5	1.5	1.0



CALCULATING AMOUNTS

How Much Do I Use?





How Much Do I Use?

Silica Gel Calculator

Silica Gel Calculators

How much Silica Gel do I need? This tool calculates the weight of SmallCorp silica gel required to maintain a microclimate in your case.

To use, simply choose English or SI units, and enter the following: 1 – The volume of the case 2 – The anticipated difference between the desired case humidity and the average ambient humidity 3 – The exchange rate for the case (# exchanges per day) 4 – The minimum time period (in days) before the gel will need to be maintained 5 – The maximum allowable deviation from the target RH%

English Units:	
Volume of case (cubic feet)	
Differential RH%	
Exchange rate/day	
Days between maintenance	
Tolerance in target RH	
Compute Clear	
Gel Required in Pounds	
Cartridges Required	
Pouches Required	

SI units:	
Volume of case (cubic meters)	
Differential RH%	
Exchange rate/day	
Days between maintenance	
Tolerance in target RH	
Compute Clear	
Gel Required in Kilograms	
Cartridges Required	
Pouches Required	

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- Affordable
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Art Sorb Calculator

○ Full Cassette
○ Half Cassette
◉ Loose Beads

3 calculate 1

input volume (ft^3) — Amount of Loose Beads (lbs)

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How Much Do I Use?

$$Q = \frac{C_{eq}\, D\, V\, N\, t}{M_H\, F}$$

Where

Q = recommended quantity of dry sorbents (kg)[a]

C_{eq} = concentration of water vapour at equilibrium (g/m^3)[b]

D = decimal difference between the RH outside the enclosure and the targeted RH inside (no unit)[c]

V = net volume of air in the enclosure (m^3)

N = air exchange rate (1/day)[d]

t = minimum number of days the targeted RH range must be maintained (days)[e]

M_H = specific moisture reservoir of sorbent, including the effect of hysteresis (g/kg for a 1% RH change)

F = targeted range of RH fluctuation (%)[f]

Jean Tétreault and Paul Bégin, 2018

https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/technical-bulletins/silica-gel-relative-humidity.html#a11b

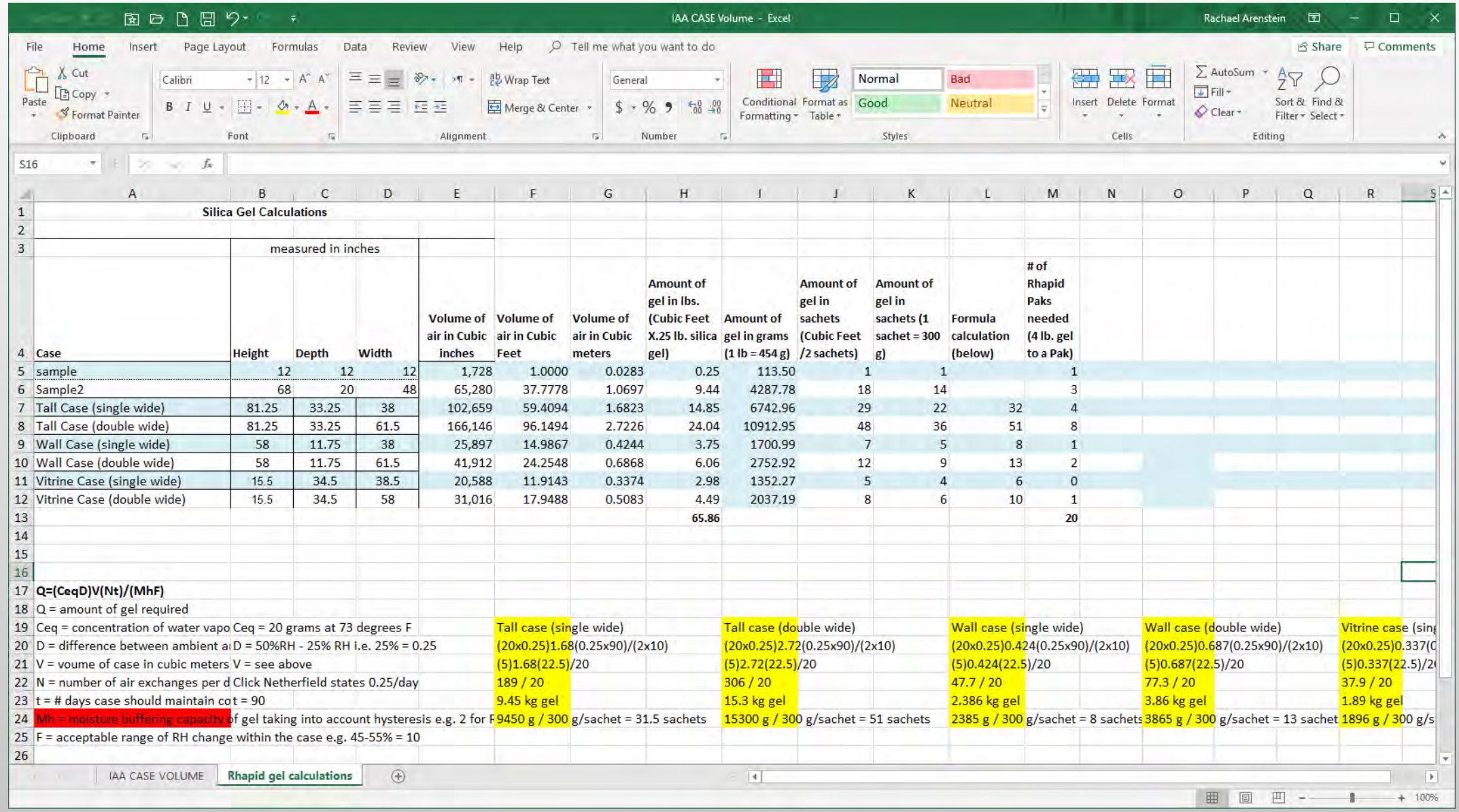
How Much Do I Use?...and how much will it cost?

Temp D V N t M_H x F

(20.0 x 0.1 x 1 x 1 x 90) = 180 / ( ) x 20 = ( ) kg/m^3

F=20 for M_H @ 20-30 and M_H @ 40-60%

How Much Do I Use?



IAA CASE Volume - Excel — Rachael Arenstein

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Paste Cut Copy Format Painter — Calibri 12 — Wrap Text — Merge & Center — General — Conditional Formatting — Format as Table — Normal Bad Good Neutral — Insert Delete Format — AutoSum Fill Clear — Sort & Filter Find & Select

Clipboard Font Alignment Number Styles Cells Editing

S16

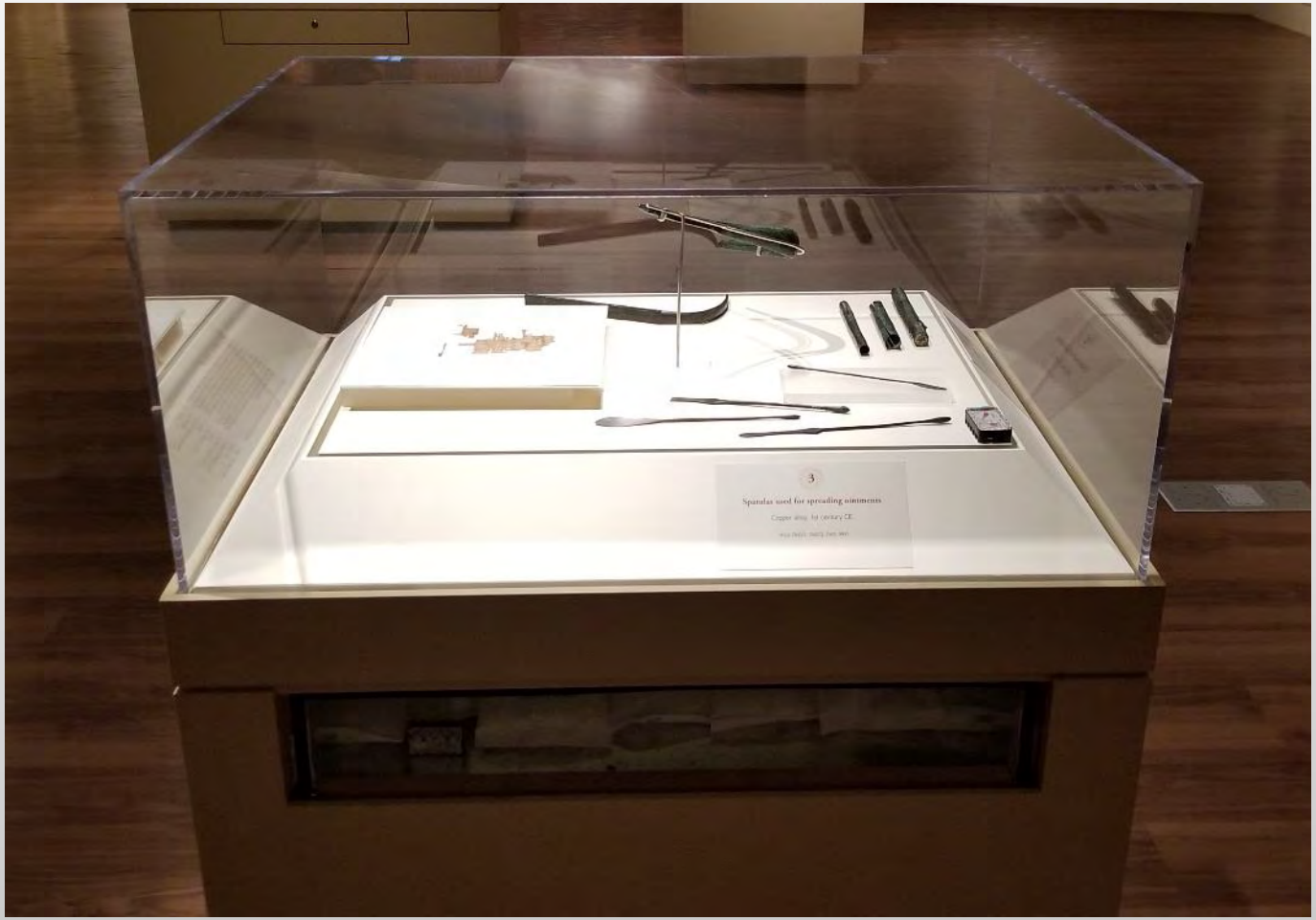
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	**Silica Gel Calculations**																	
2																		
3		measured in inches																
4	**Case**	**Height**	**Depth**	**Width**	**Volume of air in Cubic inches**	**Volume of air in Cubic Feet**	**Volume of air in Cubic meters**	**Amount of gel in lbs. (Cubic Feet X.25 lb. silica gel)**	**Amount of gel in grams (1 lb = 454 g)**	**Amount of gel in sachets (Cubic Feet /2 sachets)**	**Amount of gel in sachets (1 sachet = 300 g)**	**Formula calculation (below)**	**# of Rhapid Paks needed (4 lb. gel to a Pak)**					
5	sample	12	12	12	1,728	1.0000	0.0283	0.25	113.50	1	1		1					
6	Sample2	68	20	48	65,280	37.7778	1.0697	9.44	4287.78	18	14		3					
7	Tall Case (single wide)	81.25	33.25	38	102,659	59.4094	1.6823	14.85	6742.96	29	22	32	4					
8	Tall Case (double wide)	81.25	33.25	61.5	166,146	96.1494	2.7226	24.04	10912.95	48	36	51	8					
9	Wall Case (single wide)	58	11.75	38	25,897	14.9867	0.4244	3.75	1700.99	7	5	8	1					
10	Wall Case (double wide)	58	11.75	61.5	41,912	24.2548	0.6868	6.06	2752.92	12	9	13	2					
11	Vitrine Case (single wide)	15.5	34.5	38.5	20,588	11.9143	0.3374	2.98	1352.27	5	4	6	0					
12	Vitrine Case (double wide)	15.5	34.5	58	31,016	17.9488	0.5083	4.49	2037.19	8	6	10	1					
13								**65.86**					**20**					
14																		
15																		
16																		
17	**Q=(CeqD)V(Nt)/(MhF)**																	
18	Q = amount of gel required																	
19	Ceq = concentration of water vapo	Ceq = 20 grams at 73 degrees F				Tall case (single wide)			Tall case (double wide)			Wall case (single wide)			Wall case (double wide)			Vitrine case (sing
20	D = difference between ambient ai	D = 50%RH - 25% RH i.e. 25% = 0.25				(20x0.25)1.68(0.25x90)/(2x10)			(20x0.25)2.72(0.25x90)/(2x10)			(20x0.25)0.424(0.25x90)/(2x10)			(20x0.25)0.687(0.25x90)/(2x10)			(20x0.25)0.337(0
21	V = voume of case in cubic meters	V = see above				(5)1.68(22.5)/20			(5)2.72(22.5)/20			(5)0.424(22.5)/20			(5)0.687(22.5)/20			(5)0.337(22.5)/2
22	N = number of air exchanges per d	Click Netherfield states 0.25/day				189 / 20			306 / 20			47.7 / 20			77.3 / 20			37.9 / 20
23	t = # days case should maintain co	t = 90				9.45 kg gel			15.3 kg gel			2.386 kg gel			3.86 kg gel			1.89 kg gel
24	Mh = moisture buffering capacity	of gel taking into account hysteresis e.g. 2 for F				9450 g / 300 g/sachet = 31.5 sachets			15300 g / 300 g/sachet = 51 sachets			2385 g / 300 g/sachet = 8 sachets			3865 g / 300 g/sachet = 13 sachet			1896 g / 300 g/s
25	F = acceptable range of RH change	within the case e.g. 45-55% = 10																
26																		

IAA CASE VOLUME | Rhapid gel calculations

100%

USING SILICA GEL

Common Mistakes



Accessing Sorbents

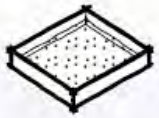
5:D Accessing Absorbers in Cases #1

Map 4

Micro-environmentally controlled cases must incorporate a practical method for accessing environmental absorbent materials (e.g. silica gel or activated charcoal). Access shouldnot interrupt the case seal , and accommodate the initial installation.

Servicing of equipment and should not require moving or contacting the display objects. Design should consider the frequency of absorber maintenance; i.e. control that requires a specific RH for the duration of an exhibit usually needs more

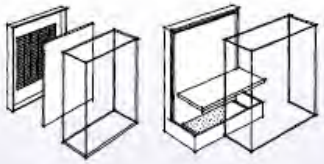
frequent access than is needed for RH buffering designs (which can run an entire year without having to access the gel). Absorbers can be loaded before objects are installed; and a small door or port can be used to access the absorber. Five methods of access are illustrated on the following pages.



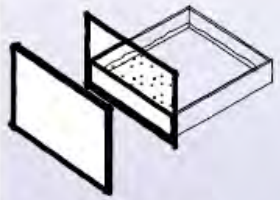
1. Access Through Display Chamber
This requires the removal of glazings or vitrines to access the moisture and pollution absorbers behind display surfaces.

Table top Case

Pedestal Case



Four and five sided Wall Case



2. Removable Access Panels
A lift-off panel or door is used to access moisture and pollutant absorber without going through the display chamber.

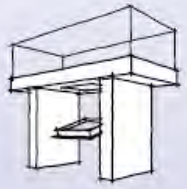
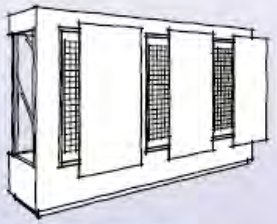


Table top Case

Pedestal Case



Wall Case

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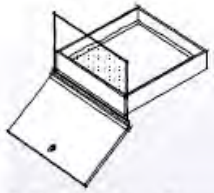
Content Development and Illustrations by Toby Raphael and Kevin Brookes

5:E Accessing Absorbers in Cases, #2

Map 5

There are five styles of access for micro-environmentally controlled cases:

1. Access through the Display Chamber
2. Removable Access Panels
3. Hinged Access Doors
4. Sliding Access Drawers
5. Prefabricated Access Doors

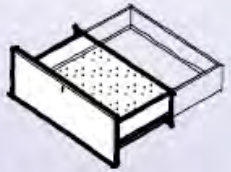


3. Hinged Access Doors
Specially designed hinged doors may be used to access absorbers without entering the display chamber. Absorbers can even be attached to the swinging door.

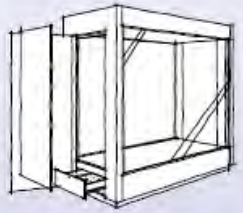
Table top Case

Double Sided Case

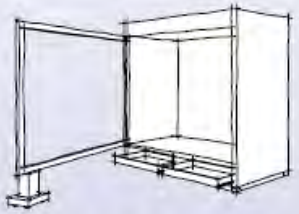
Wall mounted Case



4. Sliding Access Drawers
Conventional drawer type designs with hardware can be used to facilitate access to the absorber for installation and servicing.



Free-standing Case



Single Sided Case

Wall mounted Case

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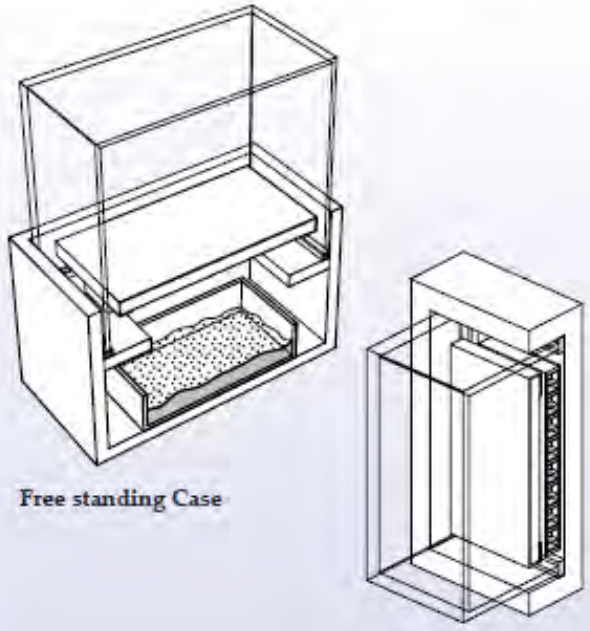
Air Circulation

5:G Air Circulation

The successful performance of micro-environmentally controlled cases relies on uniform conditions within the enclosure. Air mixing and the even distribution of humidity are critical features that are commonly overlooked. Restricted air circulation and impermeable barriers within the display chamber keep objects from the benefits of the climate control system. Ensure that air passes freely over environmental absorbers and that conditions are quickly equalized within all areas of the display chamber. To ensure adequate air circulation two methods are commonly used:

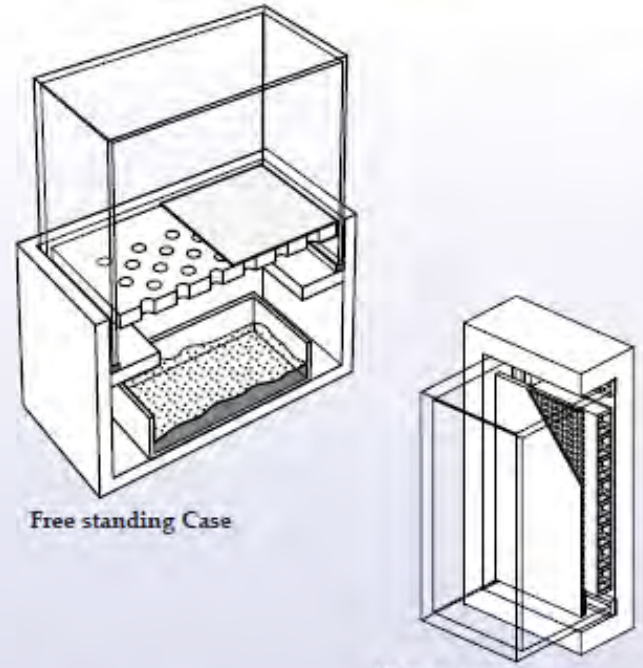
1. a sufficient perimeter gap on all sides of the display platform or deck; leave as large a gap as possible for air movement into the maintenance chamber (from 5/8 to 1" diameter for small and average size vitrines); or
2. a perforated display deck or plinth (the surface should be at least 40% open). Avoid drilling wood products, it is best to fabricate from metal or conservation appropriate plastic materials.



Free standing Case

Wall Case

Perimeter Gap
Provide a perimeter gap on all sides of deck, avoid creating air flow constrictions. Consider low CFM fans in large volume cases.



Free standing Case

Wall Case

Perforated Deck
Provide a display deck that allows air and moisture vapor to pass through it; use permeable fabrics as a covering.

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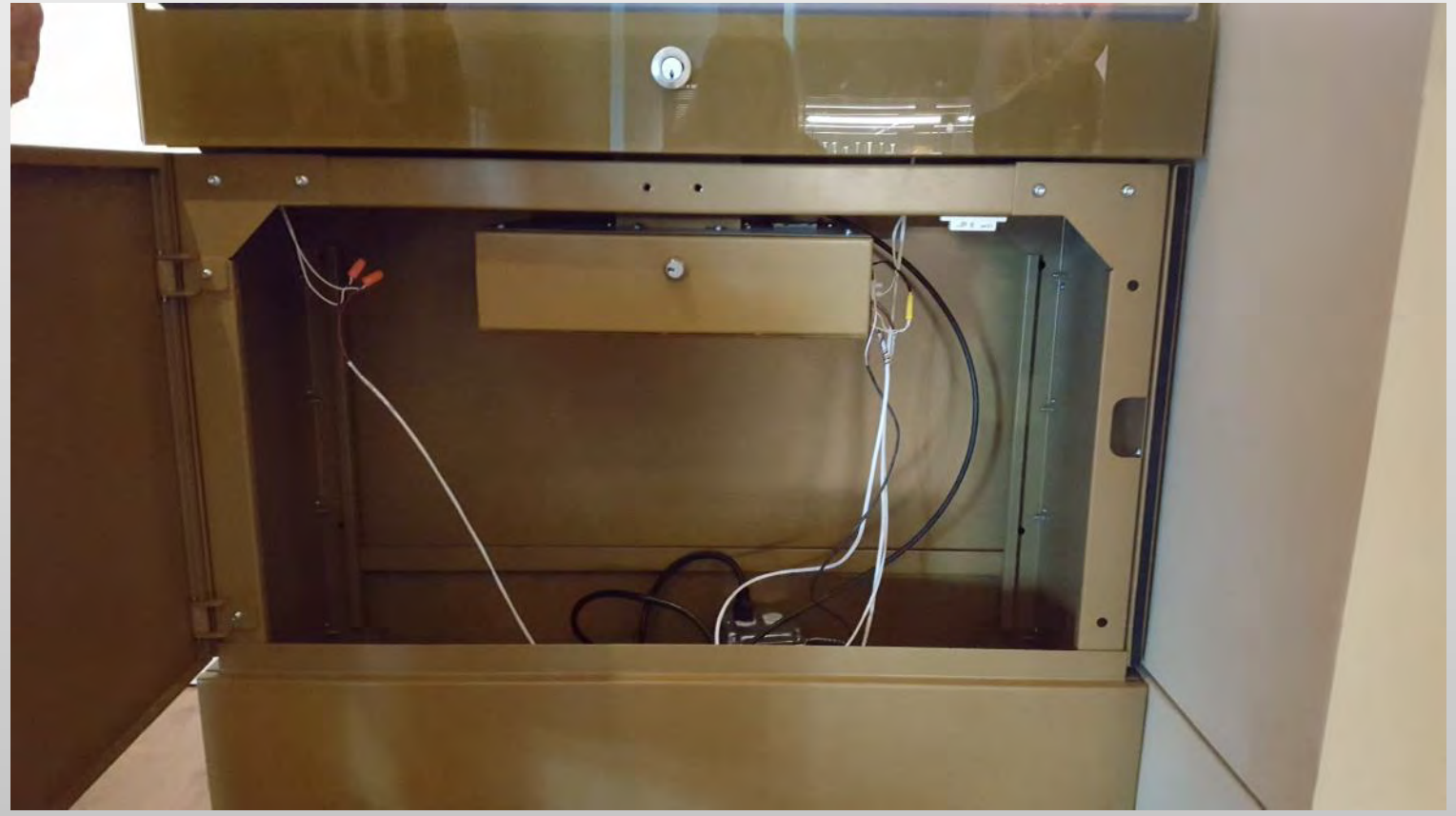
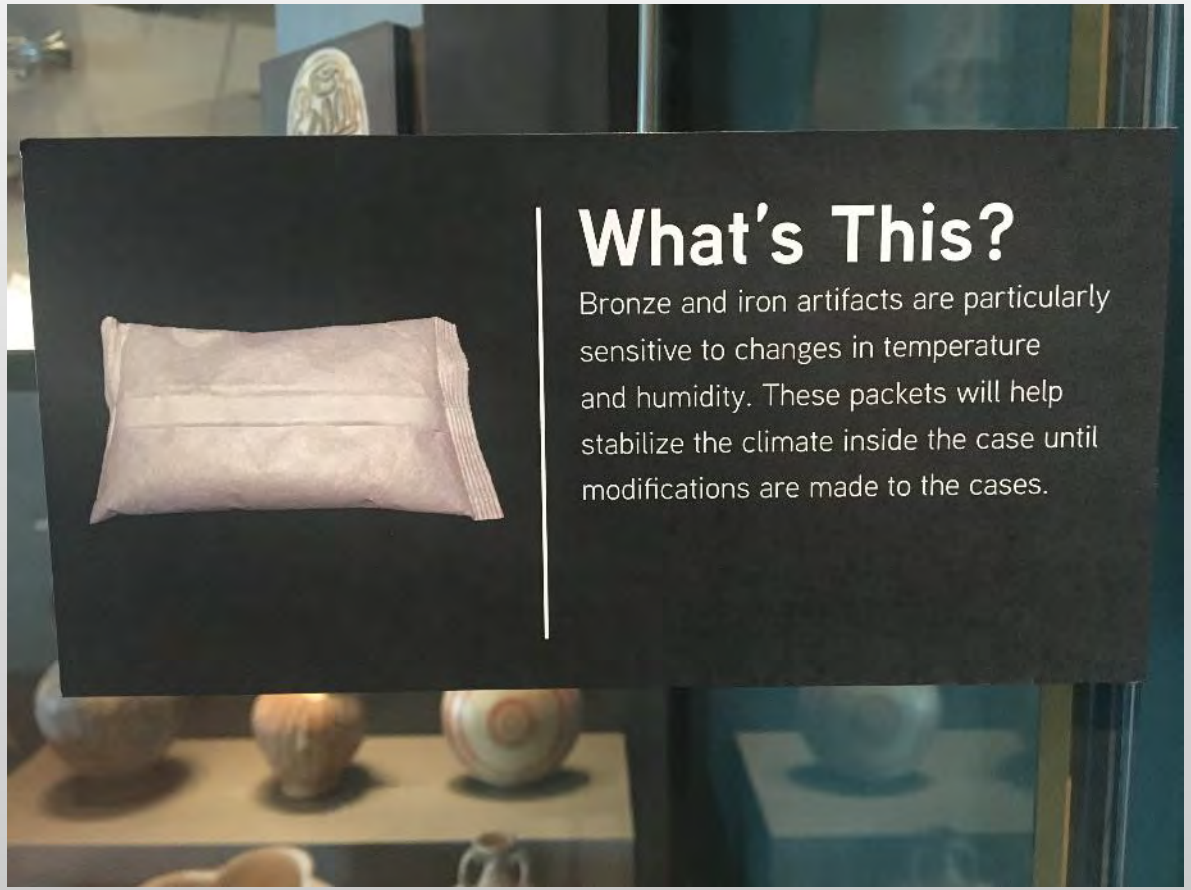
Case Construction



Circulation



Silica in the vitrine

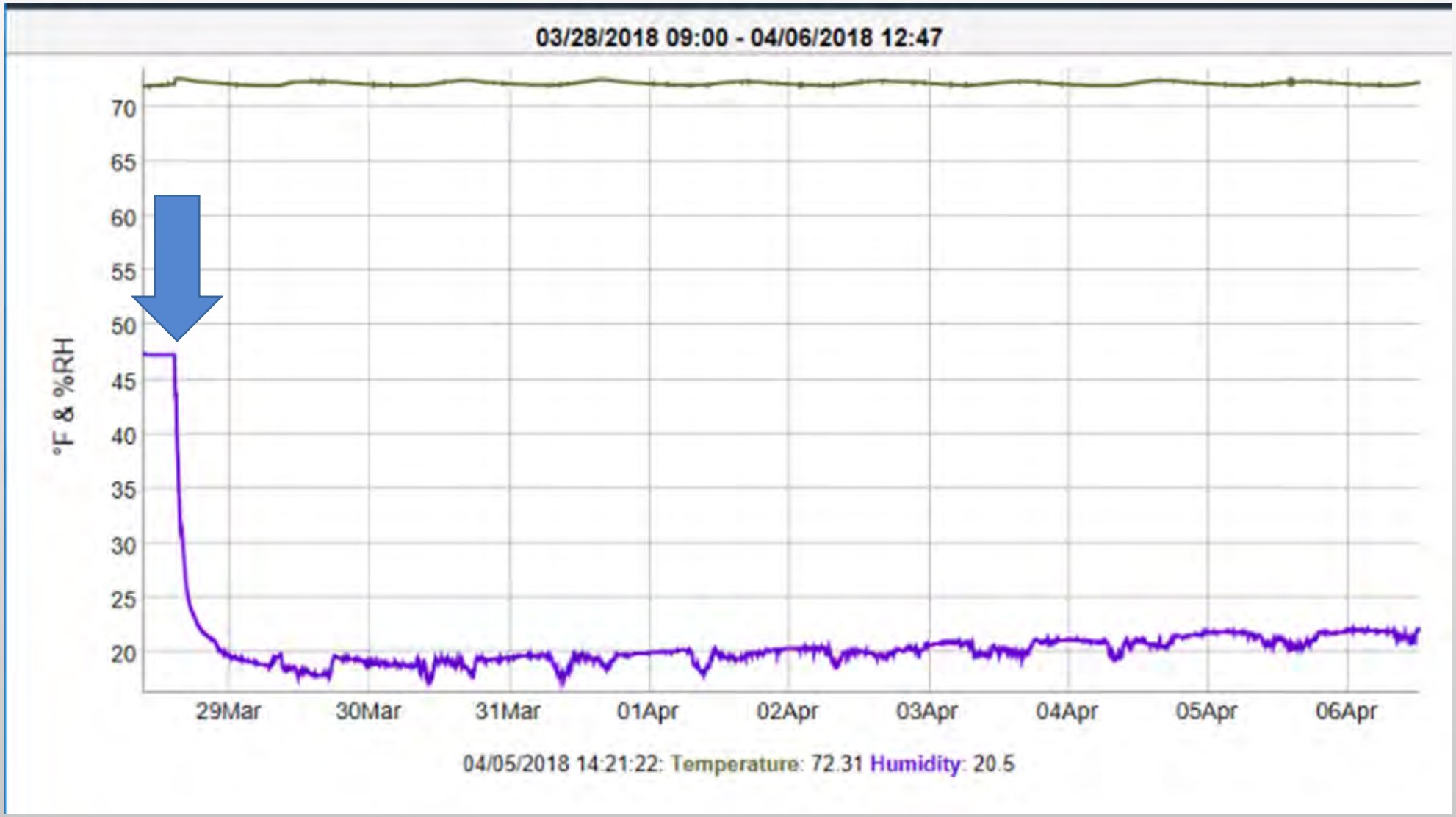
Exhibit Conservation Guidelines CD-ROM,
1999 National Park Service

Installing

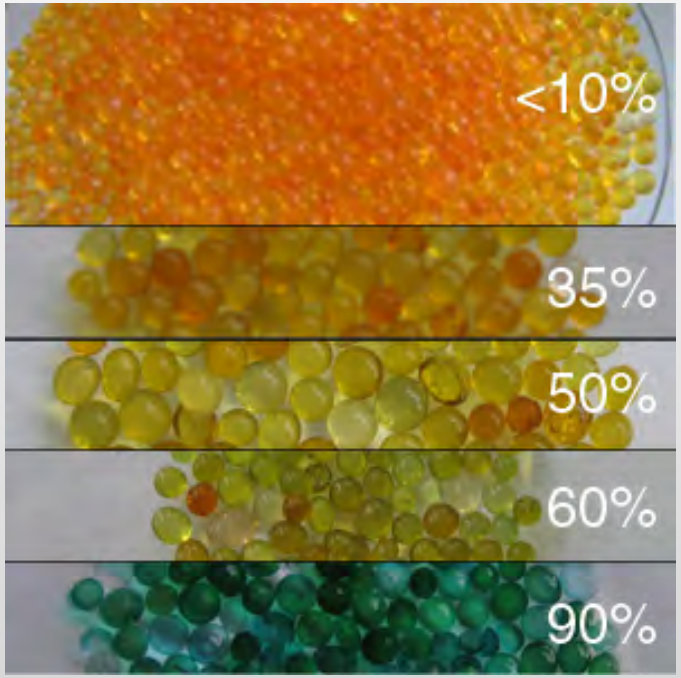
Installing


Now no blacksmith could be found in
"Lest the Hebrews make swords an
Philistines, each to sharpen his plowsha

Silica Gel In Action



Monitoring – Indicating Gels



Health & Safety

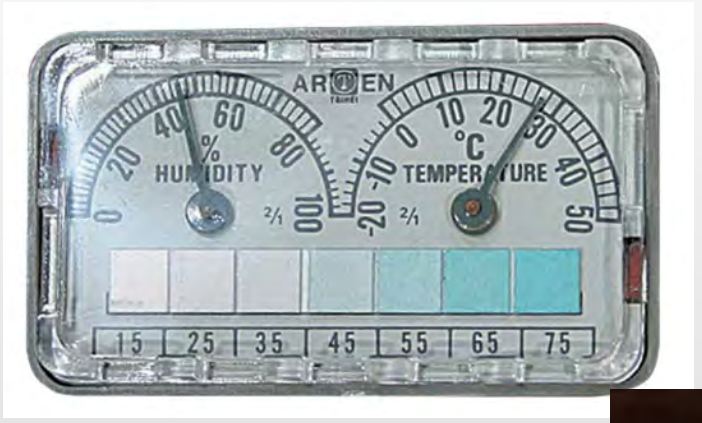
- Non-toxic and non-reactive under normal conditions.
- Avoid contact with high heat or strong acids Hazardous decomposition products:
- Health Effects Inhalation: Synthetic amorphous silica gel has little adverse effect on lungs when exposure is kept below the permitted limits but dust can aggravate medical conditions e.g. asthma.
- Eye Contact: Dust may cause discomfort and mild irritation.
- Skin Contact: Dust may have a drying effect on the skin
- Carcinogenicity: Amorphous silica is not carcinogenic to humans but additives such as color indicators like blue cobalt dichloride are.

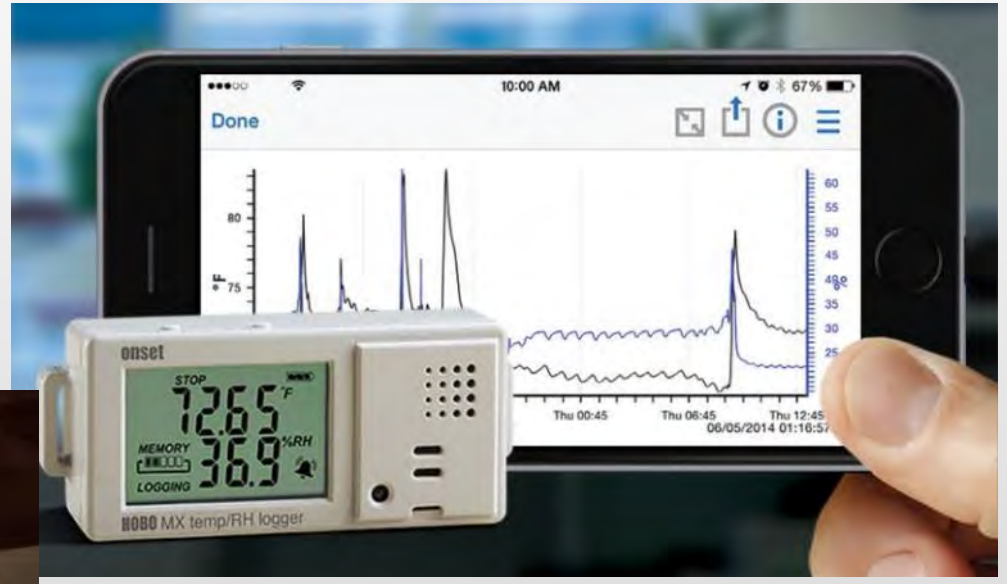
Monitoring – Humidity Indicator Cards

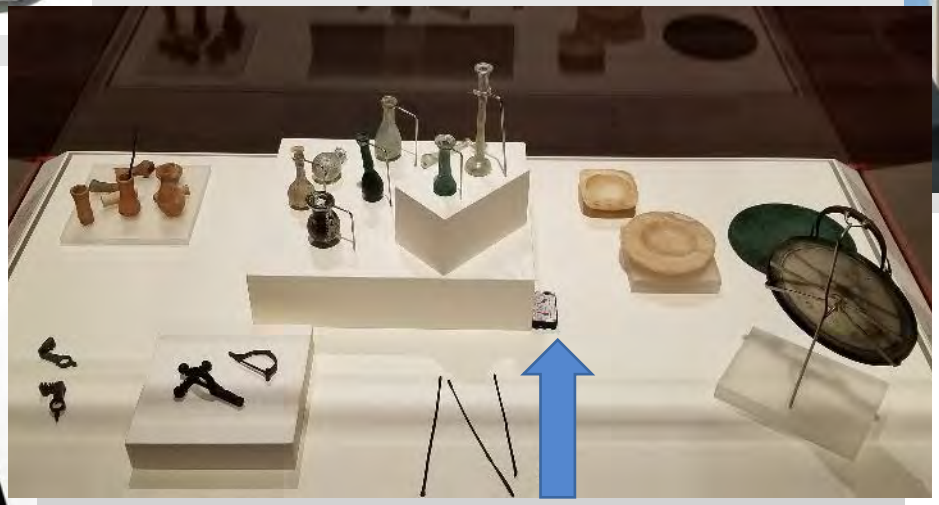
Fig. 5. Test box on shelf in storage for two years (Courtesy of Dana K. Senge)

http://resources.conservation-us.org/wp-content/uploads/sites/8/2015/03/osg021-06.pdf

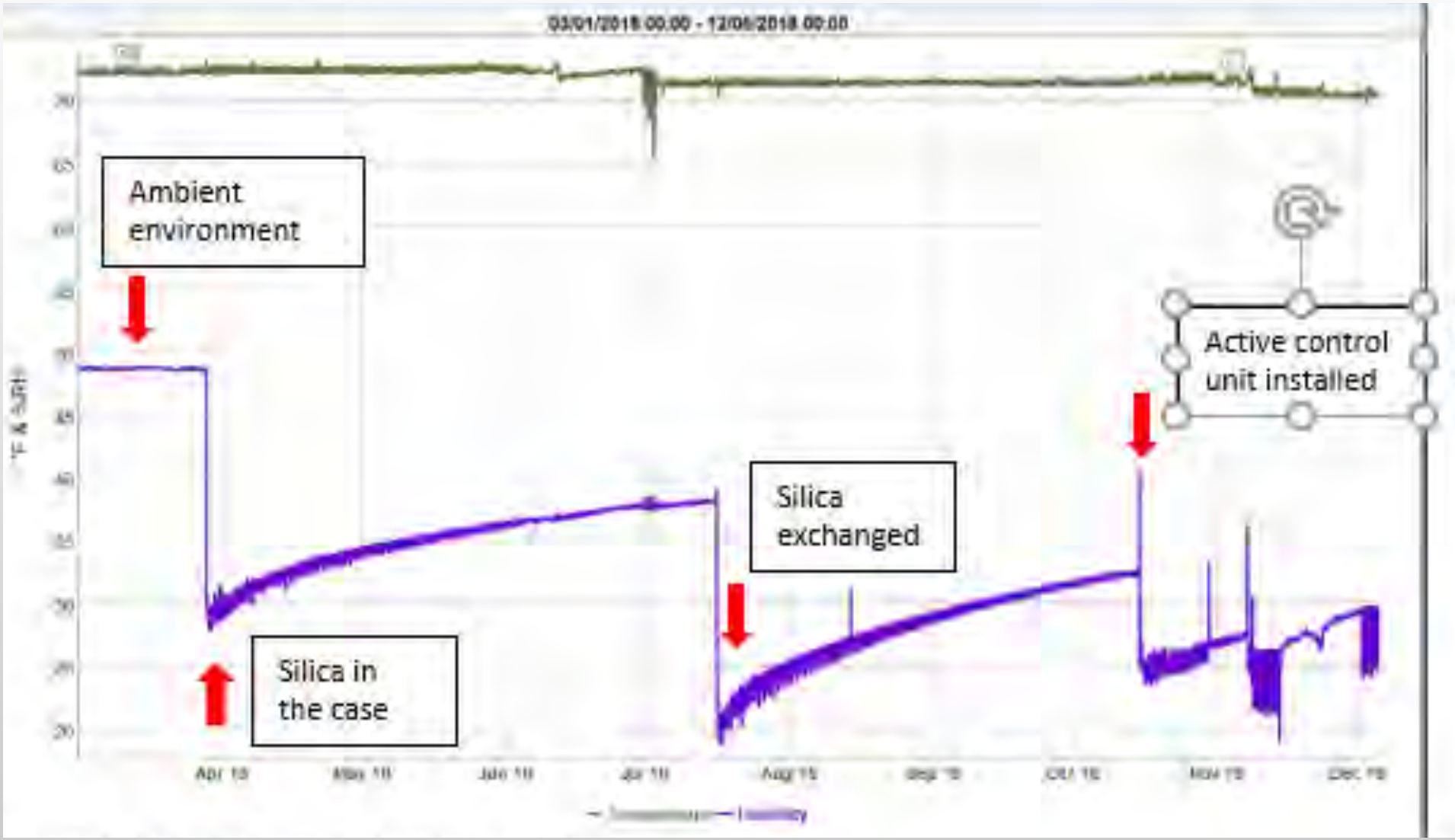
Monitoring – Thermohygrometers & Dataloggers







Monitoring


03/01/2018 00:00 - 12/06/2018 00:00
Ambient environment
Silica in the case
Silica exchanged
Active control unit installed

Drying Gel

Reconditioning Gel

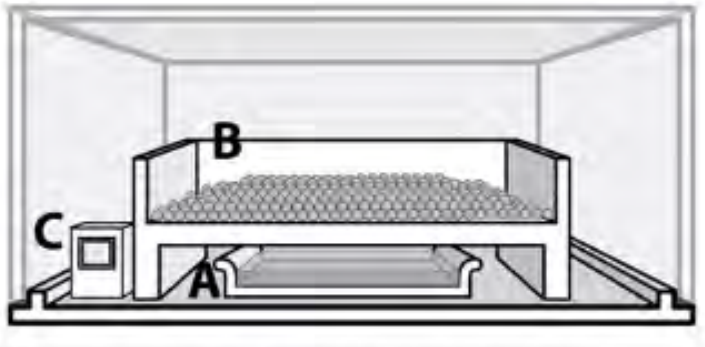


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Figure 5. Example of a small conditioning chamber.

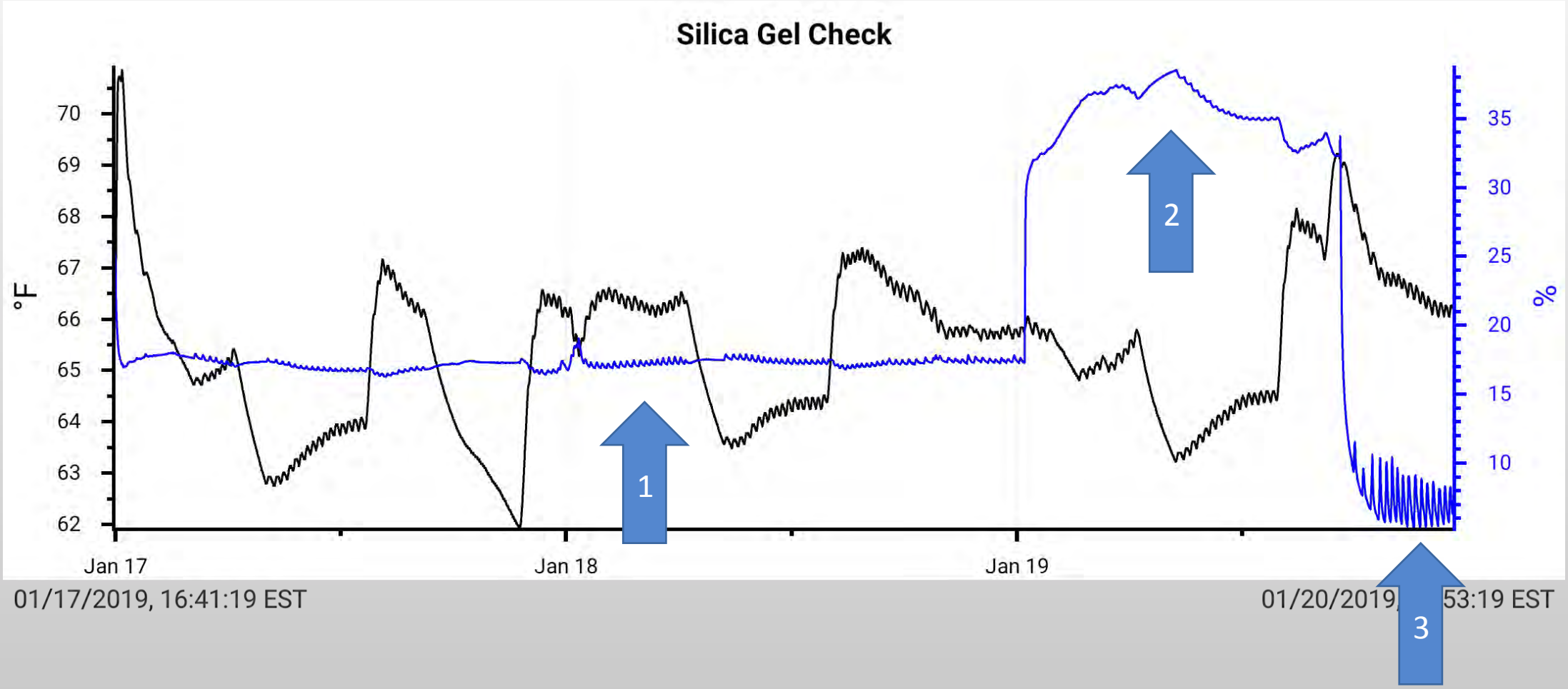
Reconditioning Tips

- Spread the gel as thin as possible.
- Use a fan to circulate air around the gel.
- Periodically mix the gel layers to improve uniformity.
- Allow time for moisture to equilibrate within and between the gel beads, especially if beads with different moisture contents are mixed together.
- Do not add water directly to gel as it can cause cracking of the beads.

Weintraub, 2002, p. 12

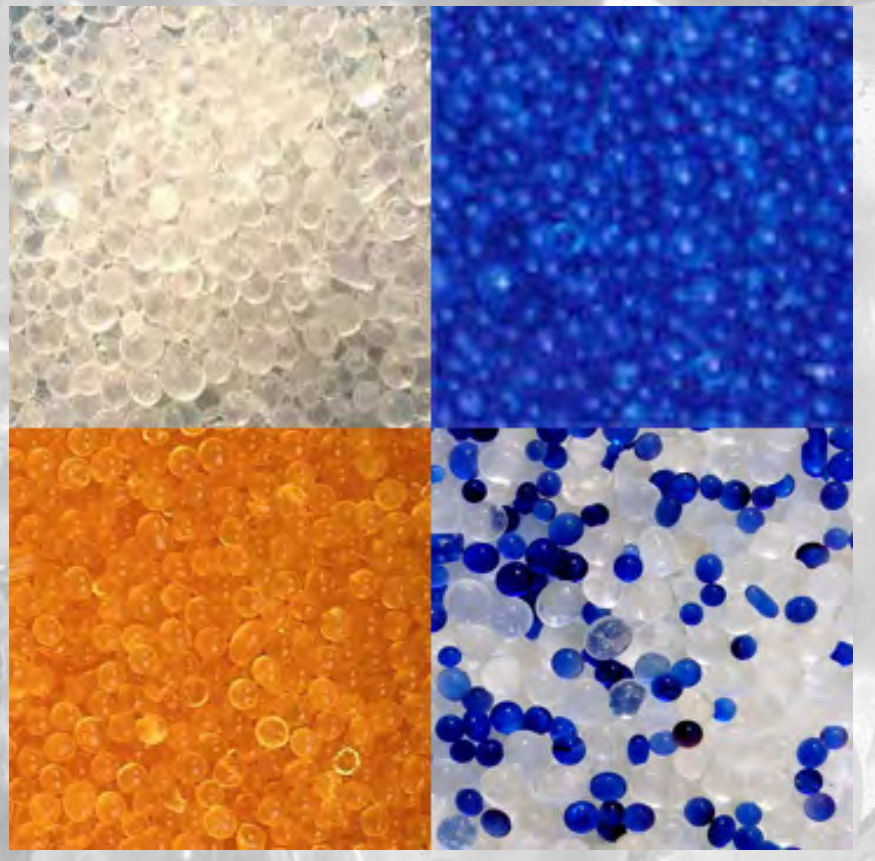
Checking Dryness

Checking Dryness



Storing Gel

SUMMING UP



Technical Resources

- Silica Gel: Passive Control of Relative Humidity – Technical Bulletin 33, Jean Tétreault and Paul Bégin, Canadian Conservation Institute https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/technical-bulletins/silica-gel-relative-humidity.html
- *Demystifying Silica Gel*, Steve Weintraub, Art Preservation Services https://docs.wixstatic.com/ugd/cb7feb_1cb7f80734314e3ebbfa3fdd0de514e8.pdf

Vendors

- Art Preservation Services https://www.apsnyc.com/
- Carr McLean (Canada) https://www.carrmclean.ca/
- Gaylord https://www.gaylord.com/
- Keepsafe Microclimate Systems http://www.keepsafe.ca/
- Long Life for Art (Europe) http://www.cwaller.de/english.htm
- SmallCorp https://www.smallcorp.com/
- Talas https://www.talasonline.com/
- University Products https://www.universityproducts.com/

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- Steve Weintraub, Art Preservation Services
- Jean Tétreault, Canadian Conservation Institute
- Jerry Shiner, Keepsafe Microclimate Systems
- Stephen Gorman, Museum of the Bible
- FAIC and M. Susan Barger, Connecting to Collections Care

QUESTIONS?

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