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Environmental Monitoring Report
Spring Semester, 2017

This project asked us to set up three different types of environmental monitors in a collections space, Anthropology Storage Room 101. Our group decided to place all three in different places within the collection, to not only practice using the devices but also to compare the different environments within the space. The hygrothermograph, calibrated weekly with a psychrometer, was placed in the open air, in a back corner of the room. The PEM2 device was placed inside a Lane cabinet, and the HOBO was placed inside a much newer Delta Cabinet.

In the run-up to this project, I had the advantage of being familiar with the PEM2 device and software. The set up for these cannot be simpler; wipe the previous data with a file created in the eClimate software, place in the desired location, and walk away. Setting up the eClimate software itself was also simple, ever more simple than my experience using it for the Anthropology section because the free software does not allow for the creation of a hierarchy of locations. IPI has worked very hard, it seems, to make the PEM2s very intuitive and simple to operate, and the ability to send the device in for recalibrate also takes that problem out of your hands.

eClimate also has analysis of the data built directly into the software, and reports on the environmental data for you. The statistics and risk metrics, particularly the color-coding, make quick identification of problems and collections safety simple. Linking the user directly to the dew point calculator is also helpful, so users can use the calculator to plan approaches to correcting environmental concerns. While the graphs the software produces are useful in visually spotting problems or trends, there is lot more beyond the visualization of the data, and having the software determine the mechanical damage and mold risk that is ongoing in any collection is incredibly useful. The fact that it is calculated for you means collections professionals are more likely to use it, and improve the care of their collections. While I might personally be biased based on my previous exposure and experiences, I think the PEM was the easiest to set up as well as the most useful in measuring the impact of the collections environment on the objects.

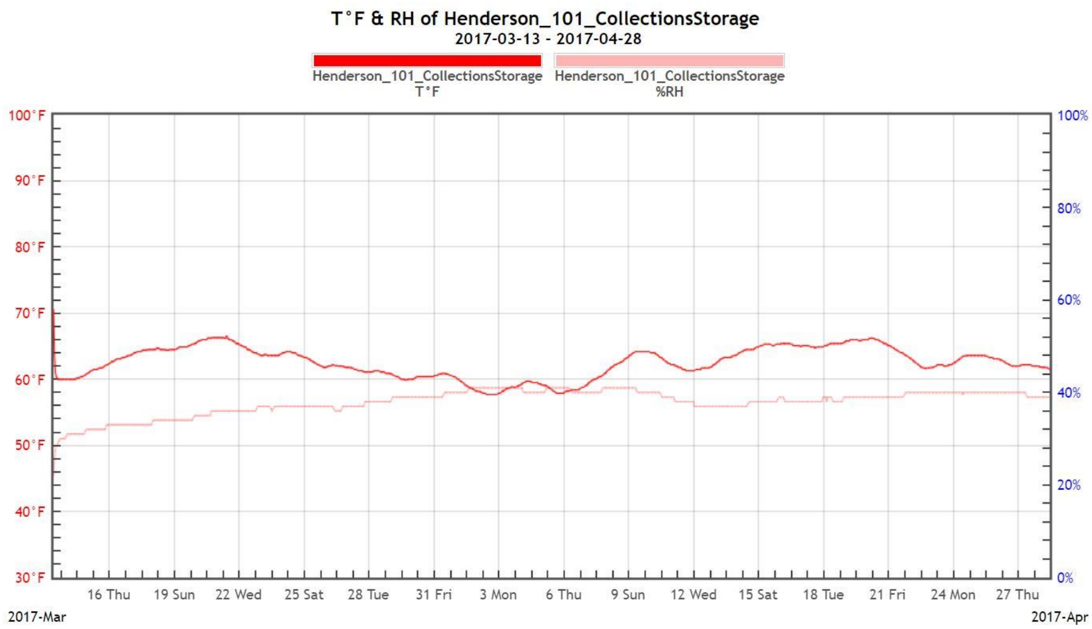


Figure 1: PEM2 Temperature and RH Data from eClimate Notebook

The hygrothermograph was not necessarily complicated to set up, but it was finicky and time-consuming to get it ready to record, and the draw-backs to using it are highlighted by the fact the pens were dried out and expensive to reorder. I also dislike the reality that the hygrothermograph is continually drifting away from a true reading and needs recalibration. Because the recalibrated should happen frequently, the data is only as good as the person and psychrometer used to do so. As we saw during this project, that can have its own confusion and problems. As it is nothing but a read out, any calculations and risk assessment must be done manually, which increases the chance of error as well the time needed to do any sort of environment assessment. Because of this, this tool would be far more time-consuming to utilize.

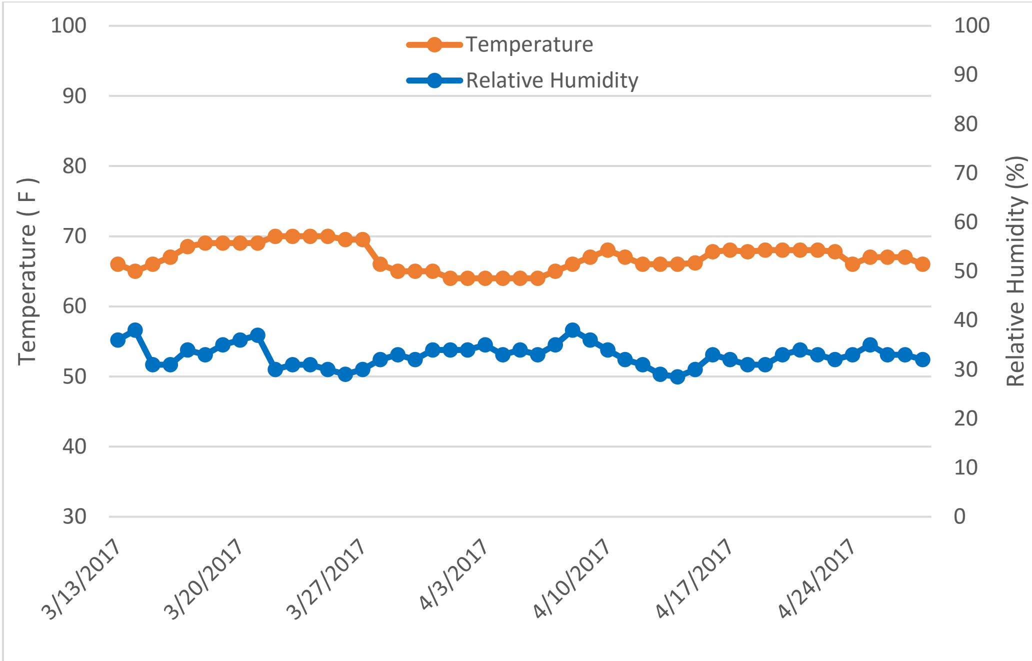


Figure 2: Hygrothermograph Temperature and RH (daily noon reading)

The HOBO was far and away the least intuitive to set up, and with its need for a laptop in the space and extra cords, also the least simple to readout. There was a lack of clarity provided by the instructions in the use and application of the different parameters that needed to be set before recording could begin, which made set-up take longer than the other devices. However, the HOBOware software, while lacking in the preservation metrics eClimate has, allows for the data to be exported to Excel, which is a useful feature. It also shows when the monitor is checked, which can account for unusual spikes in the data, as seen in our HOBO chart, when the monitor was removed from the cabinets.

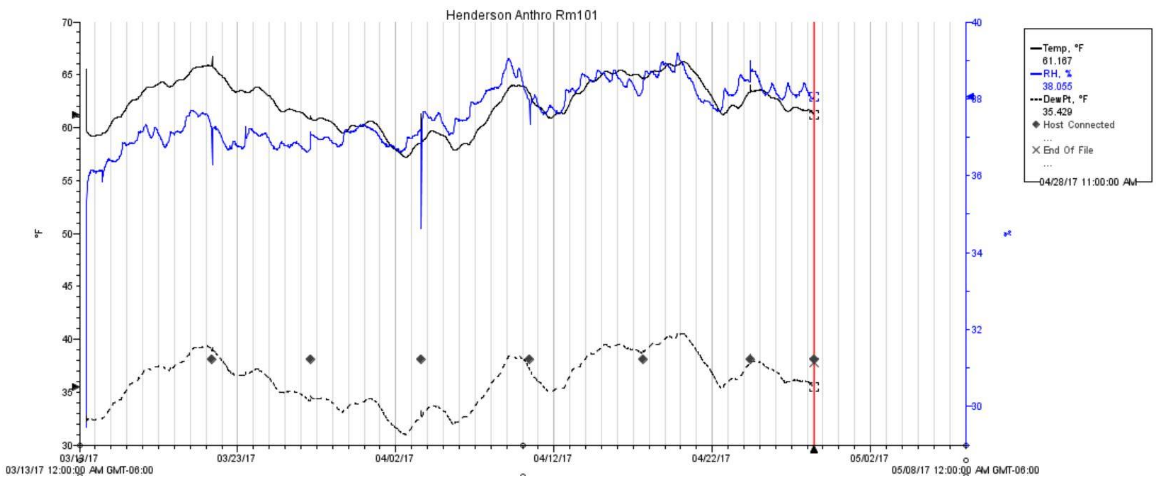


Figure 3: HOBO Temperature, RH Data, and Dew Point from HOBOware

With all this in mind, I would want to implement the PEM2s in a collection I manage. The last nine months has taught me that a collections manager really does not have the time to do assessment of the environment frequently, and if a software is out there that can tell you at a glance whether your collections are in danger, this is the most useful. The software can easily compare and track of multiple rooms worth of data and the interface is very easy to manipulate to show the data you need. While these monitors are very expensive, as is a high-level eClimate account, it facilitates a more usable set of data, with metrics that can be easily utilized for the care of the collections, so I think it is worth it. The ease of data collection for the PEM2s overall is also a deciding factor.

Not only did this project test the usability of the different monitors, it also tested the environmental metrics at different points in the room. Room 101 is one of the larger storage spaces for the anthropology department, has a long exterior wall, and has several different storage options. A large portion of the collections are stored in Lane cabinets, the older but most common type of storage for the collections at CUMNH. The museum also has several, more fragile collections in two Delta storage cabinets, a newer type of cabinet that purports to be a better environmental envelope than older options.[1] In Room 101, a large amount of archaeological material is stored in boxes on opening shelving, without any environmental envelope.

See Attached Photographs of Monitors in Place

Examining temperature first, across all three devices, it is clear that the HOBO and PEM2 data are nearly identical; so identical that they obscure one another. The hygrothermograph, however, does not match so closely.

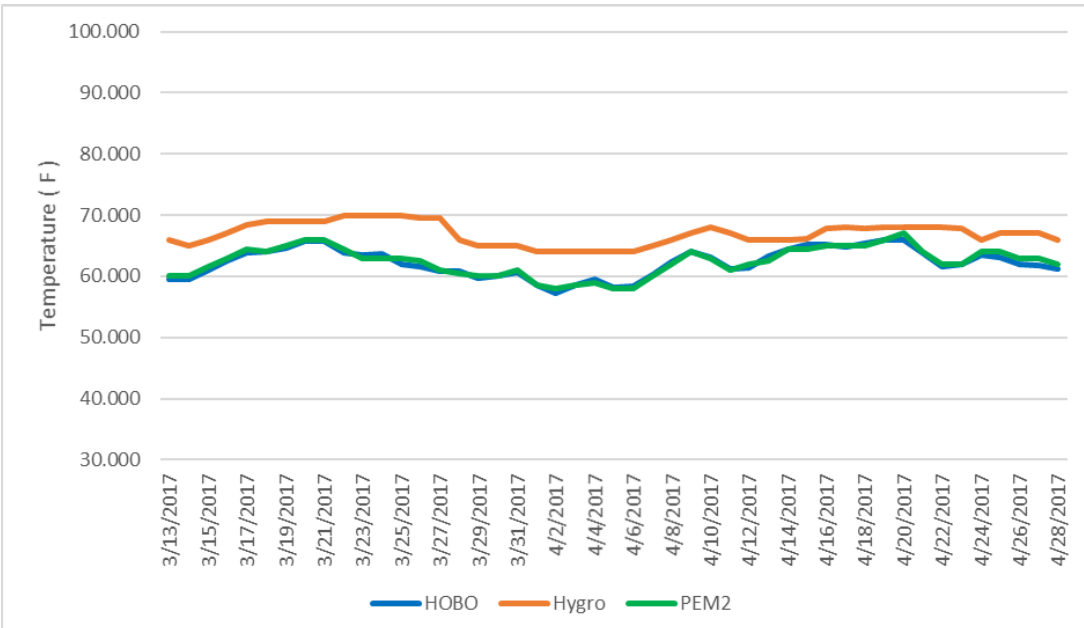


Figure 4: Temperature Across Three Monitors

The two cabinets are doing a strikingly similar job of controlling the temperature. While the hygrothermograph follows a similar shape, reacting to the external environment in the same ways and seemingly to the same extent, judging by the near constant difference, it demonstrates the open air is several degrees warmer than the cabinets. This is most likely because the cabinets are placed against an exterior wall in an old building with poor insulation, and the cinder block

[1] Delta Design Limited; Cabinet Specifications.

walls conduct the cold into the metal cabinets. These graphs demonstrate that cabinets to do not seem to do a great deal to mitigate fluctuations in the temperature, but do maintain a consistently lower temperature.

Comparing the temperature from all three devices outside to that outdoors, all three environments protected the collections from the large fluctuations, although all three reacted seem more reactive, comparatively, to increases rather than decreases in temperature. This may mean that the building's environmental control has poorer cooling than warming capabilities, and other, localized controls might be considered.

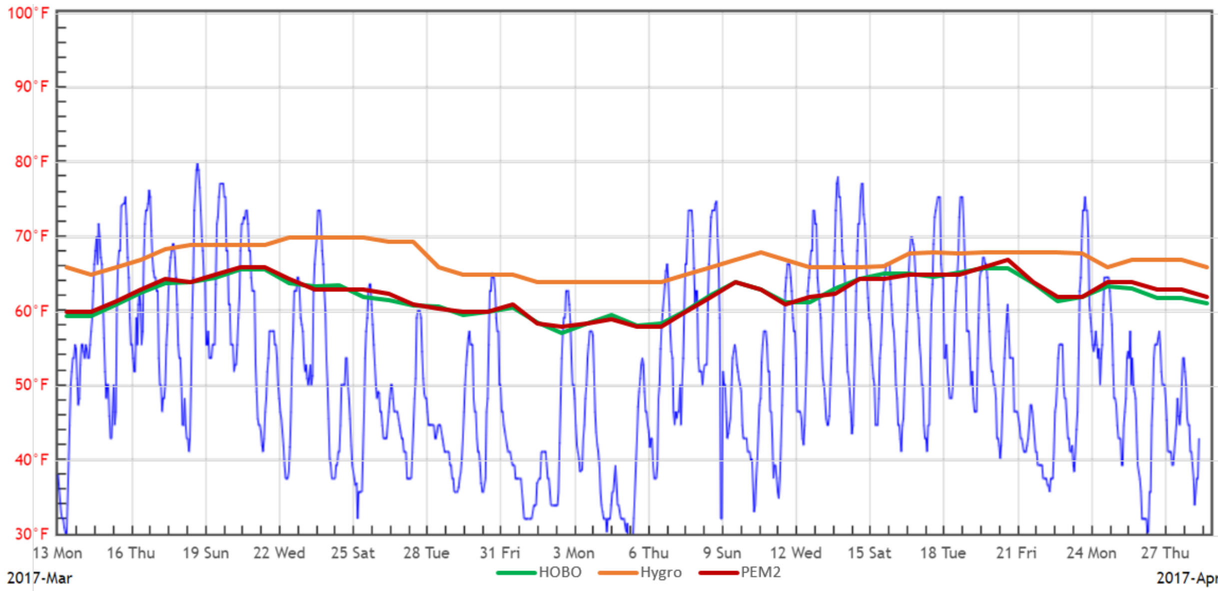


Figure 5: Outdoor and Room 101 Temperature

Collections need a stable environment for ideal preservation; this applies to the relative humidity, or RH, of the environment as well.

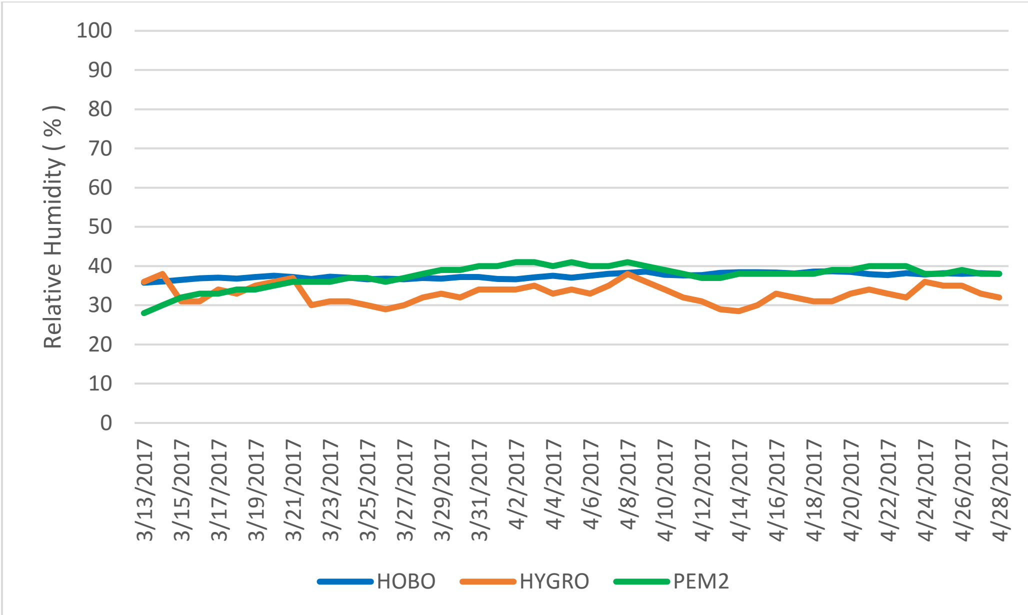


Figure 6: Relative Humidity Across Three Monitors

While the temperature graph showed remarkable consistency in reaction, the RH graph does not. The hygrothermograph in particular is very irregular, indicating that without some kind of smaller, closed environment, the air reacts much more dramatically to external factors. This reading may also be effected by the opening of the door into the collection and the presence of people near the machine, whereas the two devices in the cabinets would be more protected from such small fluctuations. However, the irregularity may also be a result of the monitor; the machine needed to be recalibrated frequently, meaning that throughout the collection period it was drifting from a true reading, and while care was taken in reading the resulting data, the data read out is not as exact as that from the other two devices.

The graph also demonstrates that while the HOBO and PEM2 device correlate much closer to one another, the HOBO still demonstrates a much more stable RH than the PEM2. This indicates that the Delta is better at controlling RH than the Lane cabinet, with a better gasket seal for the doors being the most likely cause. However, both are more stable than the hygrothermograph.

The averages for temperature, relative humidity, and dew point for all three devices were calculated across the six-week project, to determine the preservation levels for materials under these conditions. Imputing these into dpcal.org not only allowed us to check that these averages all correlate across all three metrics, but computes the effects on collections in an easy-to-read table. This is built into eClimate as well, but appears to use the same calculations as dpcalc.org (understandable, both coming from IPI). The advantage to using eClimate's built in Risk Management tool is that it also calculates risk based on the fluctuations rather than a snapshot of the data.

	HOBO	Hygro	PEM2
Average Temperature	62.22651064	66.93829787	62.42553191
Average RH	37.50046809	32.86170213	37.53191489
Average Dew Point	35.83170213	36.41177793	35.88348561
Temperature Range	8.669	6	9
RH Range	2.924	9.5	13
Dew Point Range	9.091	9.719510242	14.36377678

Table 1: Device Metrics

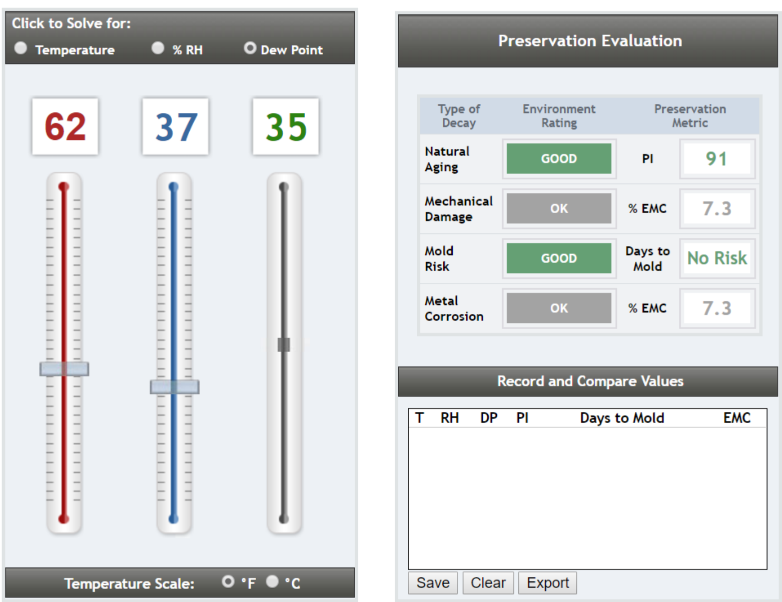


Figure 7: Risk Metrics, HOBO

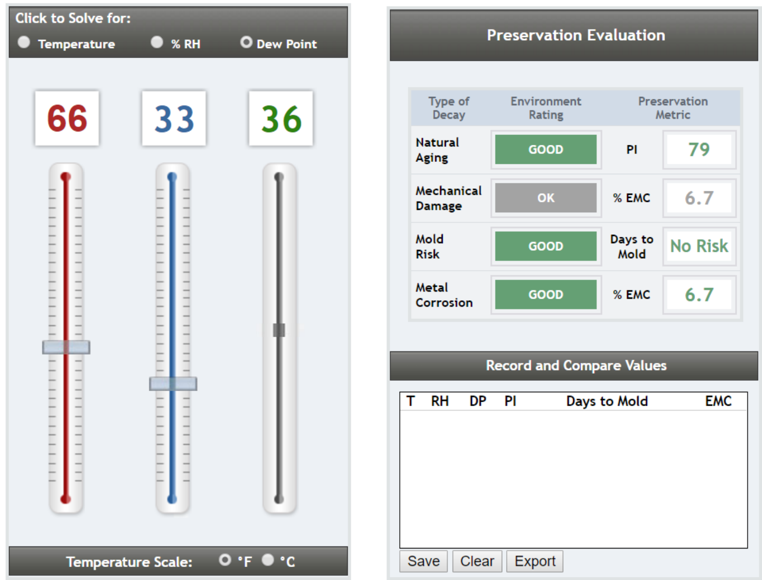
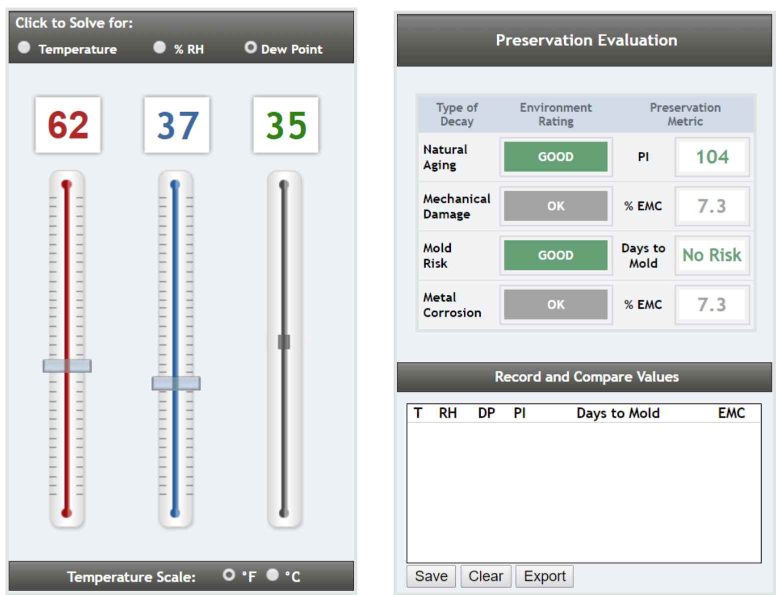


Figure 8: Risk Metric, Hygro



Henderson_101_CollectionsStorage

Risk Summary		Preservation Metrics		Data Overview	
Natural Aging	GOOD	TWPI	92	Start	2017-03-13
Mold Risk	GOOD	MRF	0	End	2017-04-28
Metal Corrosion	OK	%EMC Max	7.6	T°F Mean	62.5
Mechanical Damage	GOOD	%EMC Min	7.3	%RH Mean	38
		%DC Max	0.08	DP°F Mean	36.4

Figure 9 & 10: Risk Metrics, PEM2

All of these show the preservation environment is, on average, fairly good across all of the monitored locations, including the open air. Natural aging and mold risk are in the ‘good’ range, while mechanical damage and metal corrosion are sitting in the 'OK' range. It is notable that after adjusting the dpcal tool quite a bit, I was unable to get all four metrics to sit in the 'good' range, so this may not be achievable. Because there is very little metal in this space, this is a reasonable average. Interestingly, the assessment built into eClimate gave an even more positive look on the environment; this reading would indicate that by dropping the RH a bit more we may be able to achieve a near-ideal environment (although this metric does not take specific materials into consideration).

While the averages are good, it very important to see the fluctuations, which is why the graphs are useful. Evident in the chart above, there is too much fluctuation across all three devices, as ideally there would be no more than a 3% fluctuation in RH and, over this time period, no more than 5-7 degree fluctuations.[2] For ideal preservation, tighter control is needed. Also, the metrics indicating the amount of damage being done are not as ideal as they could be even for the average samples. For example, the Time Weighted Preservation Index is only at 79 days for the HOBO readings, and while the tool still classifies this as 'good,' I'd prefer if this number was higher. However, the environment indicated is not causing active damage to the objects.

In this room, I believe the most important metrics to pay attention to are natural aging (chemical decay as based on spontaneous chemical changes in organic materials) and the mechanical damage (physical or structural deterioration) metrics.[3] Unless the humidity gets immensely out of hand, mold is not a major concern, and within this storage space there is not a great deal of metal stored. This reading is based only upon short-term evaluation, however, and

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[2] *Conservation Considerations for Archaeology Collections*. Care of Collections Series, Sherelyn Ogden, Project Director. Minnesota Historical Society.

[3] Ford, Patricia et al. *Sustainable Preservation Practices for Managing Storage Environments* (Image Permanence Institute; Rochester Institute of Technology, 2013), 10-11.

as it seems this room is more susceptible to the outdoor environment than others, it would be useful to calculate preservation metric during the cold winter months.

Room 101 contains a variety of materials, though the majority is archaeology, stone and ceramics sherds from a large archaeological site in Colorado. Also present, among other things, is a small ethnographic collection from Asian countries, including a number of ivories, a shelf of metal weapons, some historical objects, and a set of human remains decorated with earth and paints. Significantly, the Mantles Cave collection is also stored in one of the Delta cabinets, an archaeological collection containing organic, perishable materials with unparalleled preservation, including a feathered headdress and a deer hide headdress that is over 2000 years old. An Alaskan archaeology collection, with a substantial amount of wood, ivory, and other organics is also in Room 101.

One of the challenges in Anthropology collections in the number of material types needing different environments that may be present in a given space, including more reactive organic materials, as seen here.[4] Mechanical damage and natural aging are of most concern to this space because of the presence of the organic materials in the Mantles Cave, Alaskan archaeology, Castle Park, and ivory collections, and the need to understand how much structural deterioration can be slowed with proper climate control.[5]

Different materials have different environmental needs. The Smithsonian Institute's report of relative humidity guidelines recommends a higher relative humidity level for ivory (between 37% RH and 53% RH),[6] than the MHS guide's recommendation for preserved human

[4] *Basic Preservation Considerations*. Care of Collections Series, Sherelyn Ogden, Project Director. Minnesota Historical Society.
[5] eClimate Notebook, Environmental Risk Ratings.
[6] Mecklenburg, Marion F. "Determining the Acceptable Ranges of Relative Humidity And Temperature in Museums and Galleries." Smithsonian Museum Conservation Institute, 2012.

remains, at 20%-30% RH.[7] The collections of ivory and the Vanuatu Ramparand come from places with higher natural relative humidity, at this point these objects in the CUMNH collection have acclimated to an environment which is "very dry, cold at night during the day, and has little rain," which could be a mitigating factor in determining their ideal set points.[8] [9]

The most important thing for all of these collections is avoiding large fluctuations, particularly for the ivory and wood objects. According to the IPI, maintaining a steady temperature is more important than maintaining a constant RH, as the objects react faster to temperature than to RH changes, and the Smithsonian found that even with the presence of pre-exiting stresses, most materials can easily withstand RH ranges from 30% RH to 60% RH reversibly.[10] With delicate, fragile perishable materials present, the goal is to set a range for both temperature and RH that protects the most at-risk objects, like the Mantles Cave collection, without damaging other objects.[11]

With that in mind, if only one environment could be maintained for the room, setting temperature between 50-55 F and relative humidity at 35-40% would safely preserve the collections. This meets the needs of the very delicate Mantles Cave perishable collection, the materials of which may traditionally need a slightly higher RH at about 40-50%, but being native to Colorado and archaeological in nature may do better set to the lower standard.[12] This is also

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[7] *Conservation Considerations for Archaeology Collections*. Care of Collections Series, Sherelyn Ogden, Project Director. Minnesota Historical Society.

[8] Ford, Patricia et al. Sustainable Preservation Practices for Managing Storage Environments (Image Permanence Institute; Rochester Institute of Technology, 2013), 17.

[9] *Basic Preservation Considerations*. Care of Collections Series, Sherelyn Ogden, Project Director. Minnesota Historical Society.

[10] Mecklenburg, Marion F. "Determining the Acceptable Ranges of Relative Humidity And Temperature in Museums and Galleries." Smithsonian Museum Conservation Institute, 2012.

[11] Michalski, Stefan. "The Ideal Climate, Risk Management, the ASHRAE Chapter, Proofed Fluctuations, and Toward a Full Risk Analysis Model." Contribution to the Experts' Roundtable on Sustainable Climate Management Strategies, April 2007, Tenerife, Spain. *The Getty Conservation Institute*.

[12] *Conservation Considerations for Archaeology Collections*. Care of Collections Series, Sherelyn Ogden, Project Director. Minnesota Historical Society.

suitable for both the ivory and the human remains in the collection, and keeps the RH low enough to not cause great harm to the metal in the swords. Most of the Room 101 collections need tightly controlled fluctuations, as they are more prone to embrittlement, discoloration, decay, and mold.[13] For that reason, ideally neither temperature nor RH would fluctuation more than the narrow limits given above.

If microclimates are an option, it might be wise to increase the RH (slowly) for the ivories to 42-47% and warm the temperature to 65-70 F.[14] At the standard set above, the Asian sword collection would not require special conditions; while the metal needs very low humidity to prevent corrosion (20-30% recommended by the MSH) these conditions would begin to damage the materials present in the handles.[15] The Vanuatu Rambaramp also needs special consideration. This should, according to the Minnesota Historical Society's guide, be kept at a very low RH but warmer temperature, 25-30% RH and 60-65 F, to prevent deterioration of the mud and paint yet prevent molding in any remaining tissues.[16]

IPI advises that dew point controls the type of environment that is achievable, because temperature, relative humidity, and dew point are all interrelated, and dew point (DP) is often the limiting factor on a mechanical environmental control system. Dew point is responsible for determining what temperature will result in what RH, so controlling the dew point, the absolute moisture in the air, manages the rate of material decay in the collections. In Colorado, outdoor dew points tend to be quite low, although during this analysis period there was quite a bit of rain, making the outdoor environment more humid than the indoor. With a humidity-controlled

[13] "Collections: Preserving Perishable Materials." The National Parks Service Conservation Program.
[14] "The Care and Handling of Ivory." The Smithsonian Conservation Institute.
[15] *Metals and Alloys Found in such items as jewelry, vessels, and weapons*. Care of Collections Series, Sherelyn Ogden, Project Director. Minnesota Historical Society.
[16] *Conservation Considerations for Archaeology Collections*. Care of Collections Series, Sherelyn Ogden, Project Director. Minnesota Historical Society.

system, an institution is able to correct for these fluctuations, by either dehumidifying and removing moisture from the air, or add moisture through humidification, altering temperature and RH in the collection.[17]

Dew point was calculated for this analysis, both through built-in software and through dpcalc.org. The graph below shows all three dew points from the devices. Understandably, they are very similar across all three, with the slightly more notable deviation seen in the hygothermograph most likely being accounted for by the manual data recording and calculations. Because dew point moves in tandem with temperature and humidity, this reading also reinforced how comparable the three environments are.

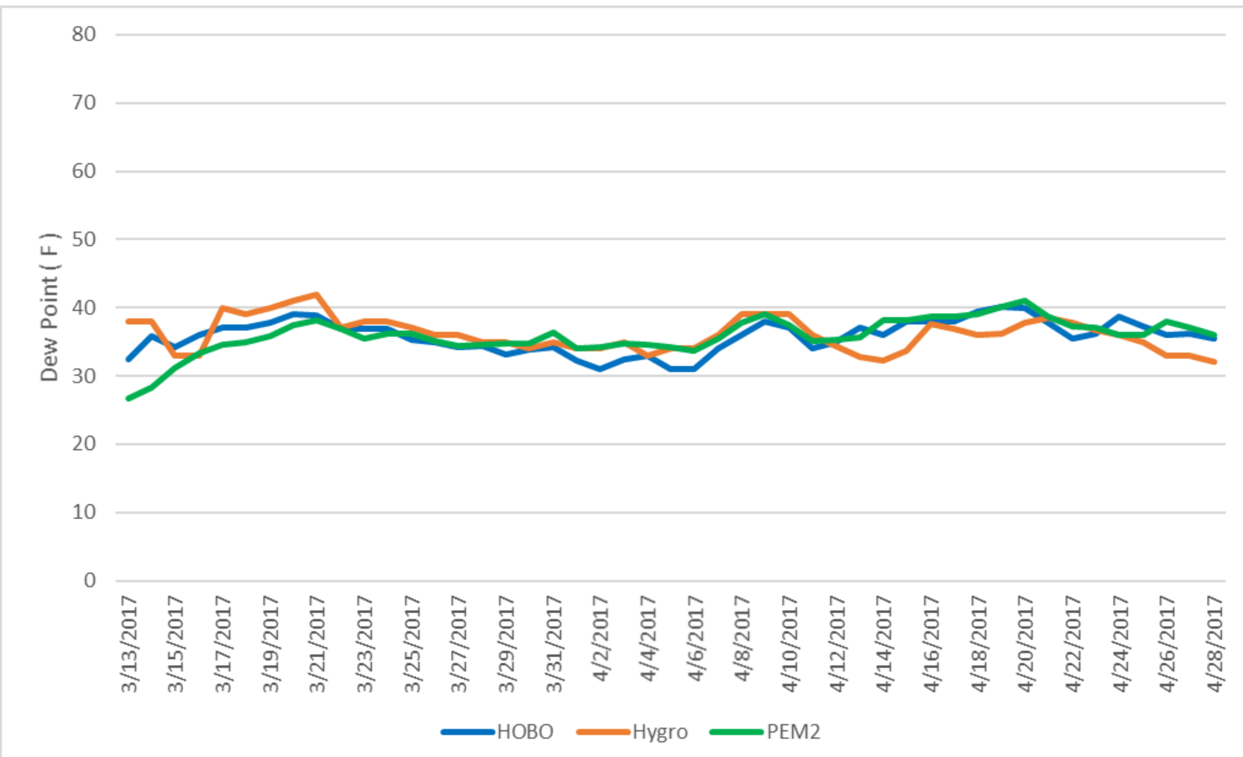


Figure 11: Dew Point Across Three Monitors

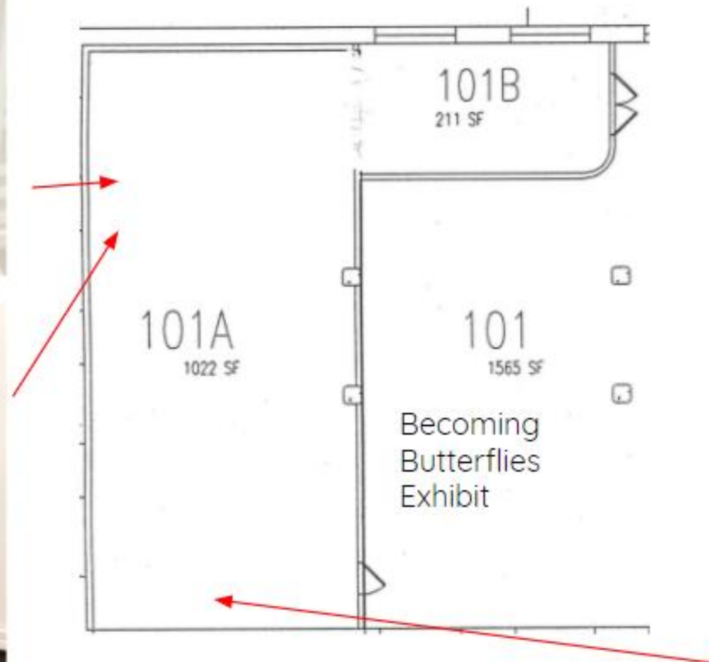
[17] Ford, Patricia et al. Sustainable Preservation Practices for Managing Storage Environments (Image Permanence Institute; Rochester Institute of Technology, 2013), 46-50.

If we were to control the dew point to reach our desired environment of 50-55 F and 35-40% relative humidity, we would want to get our dew point down to about 28 or 27 F. This means that we'd have to dehumidify the space just a bit, as it currently tends to sit in the 30's. While the idea of dehumidifying in Colorado seems strange, because we would like the collections to sit at a slightly colder temperature, to achieve the desired RH we do need to remove a bit of moisture.

Device Placement

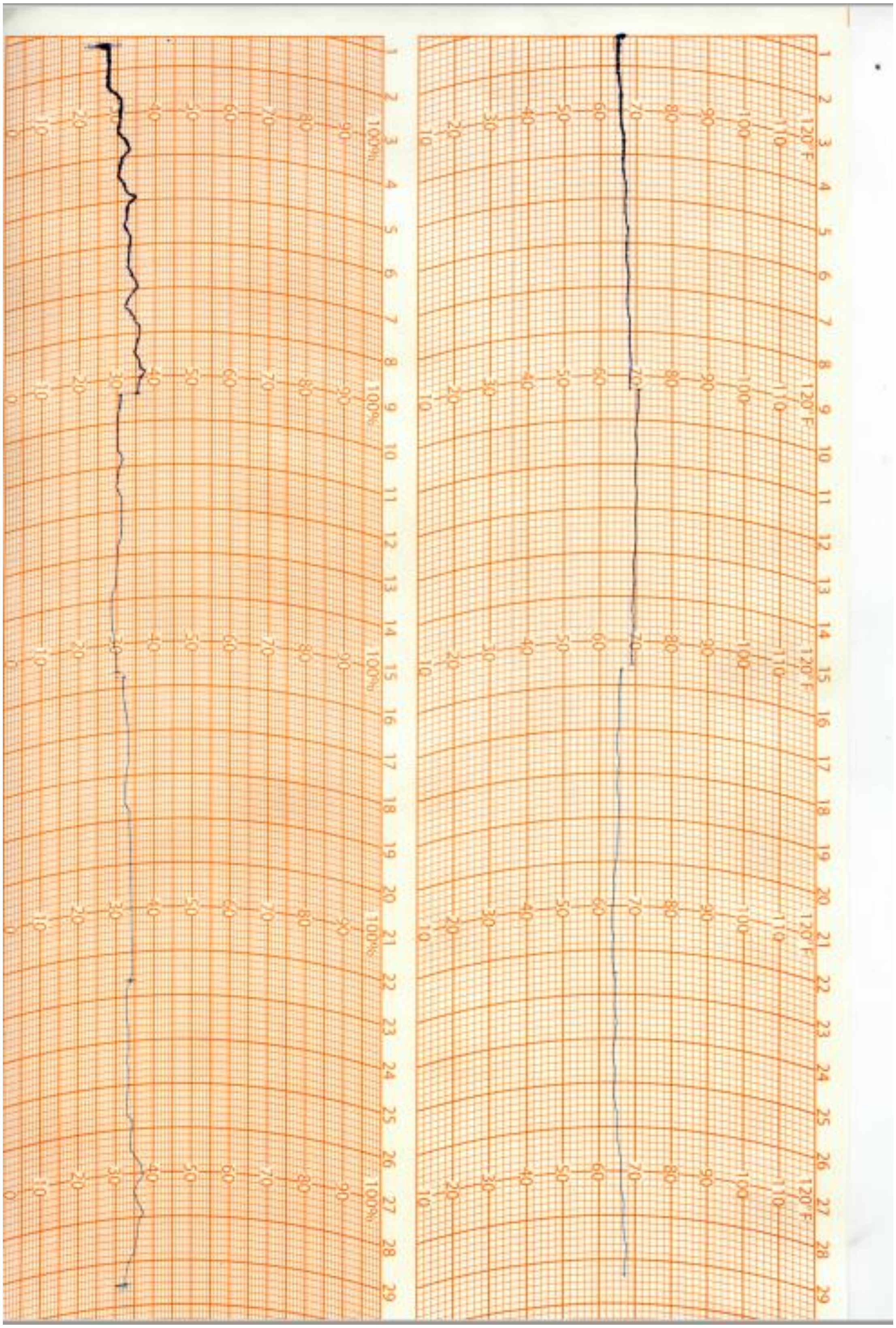
HOBO

PEM2

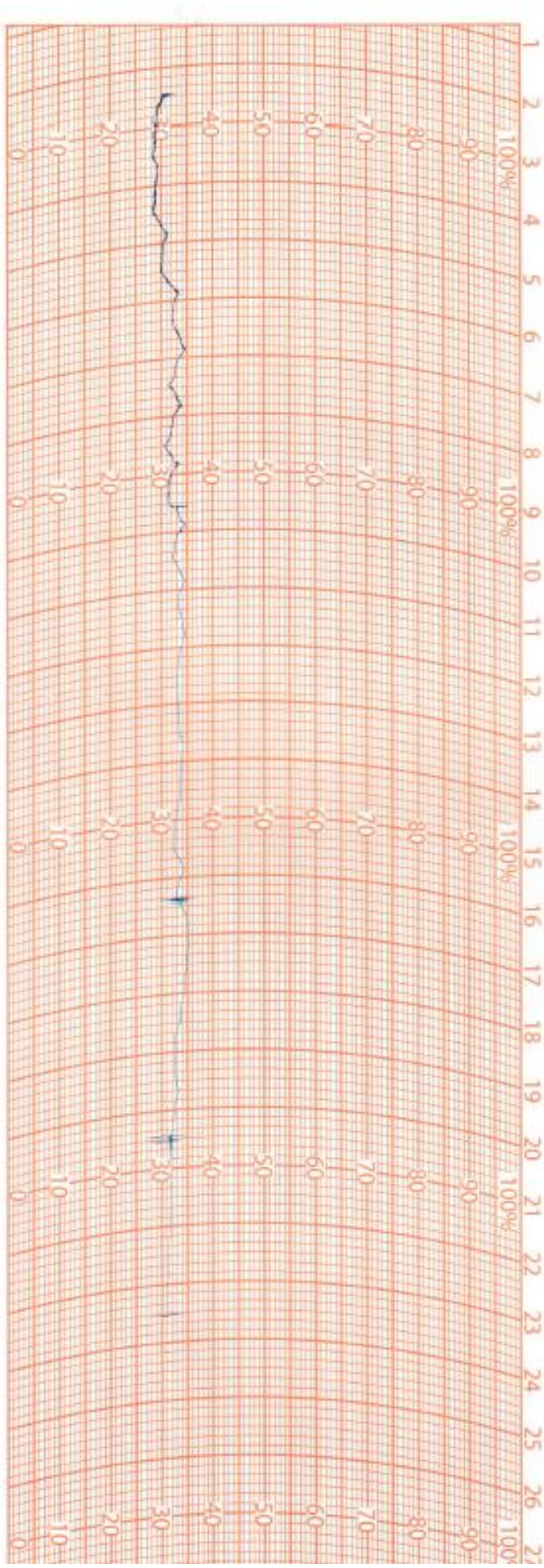


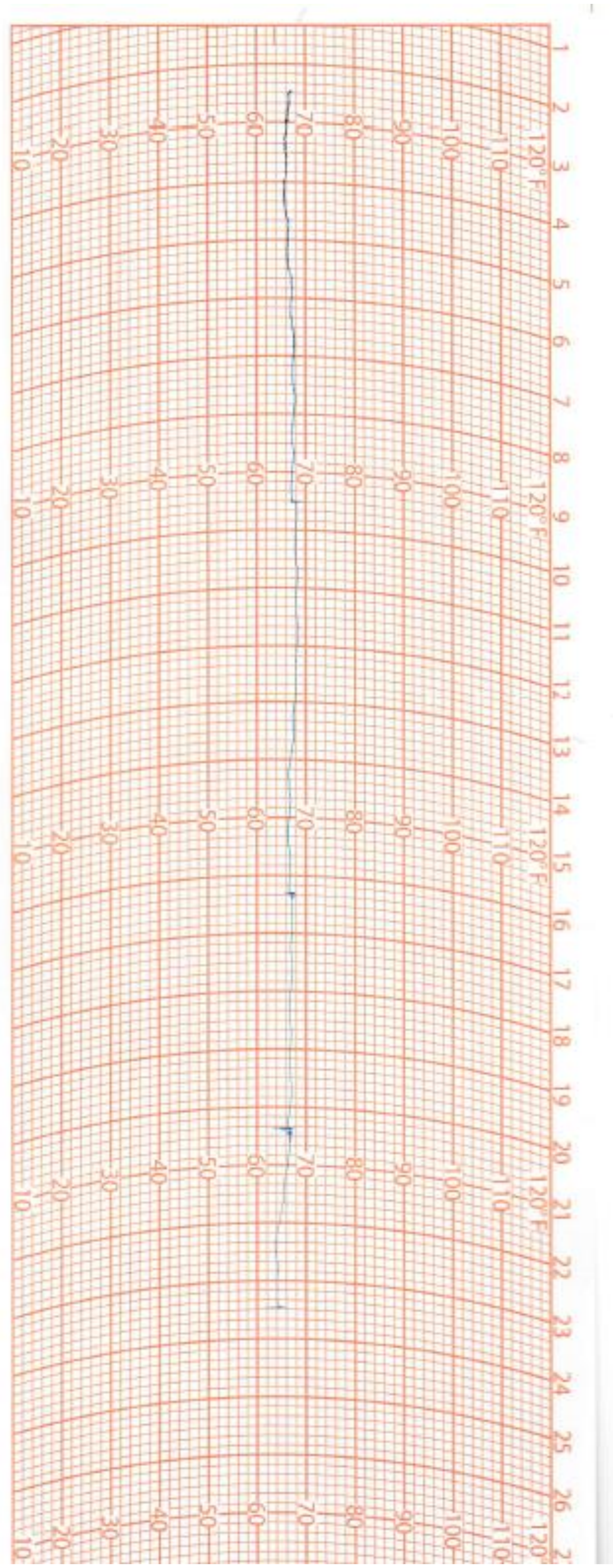
Hygrothermograph

Hygrothermograph Read-out 3/13-4/10



Hygrothermograph Read-out 4/10-5/01





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"Collections: Preserving Perishable Materials." The National Parks Service Conservation Program. https://www.nps.gov/articles/collections.htm

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Ford, Patricia et al. *Sustainable Preservation Practices for Managing Storage Environments* (Image Permanence Institute; Rochester Institute of Technology, 2013), 10-11.

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Metals and Alloys Found in such items as jewelry, vessels, and weapons. Care of Collections Series, Sherelyn Ogden, Project Director. Minnesota Historical Society. http://www.mnhs.org/preserve/conservation/connectingmn/docs_pdfs/repurposedbook-metalsandalloys.pdf

Michalski, Stefan. "The Ideal Climate, Risk Management, the ASHRAE Chapter, Proofed Fluctuations, and Toward a Full Risk Analysis Model." Contribution to the Experts' Roundtable on Sustainable Climate Management Strategies, April 2007, Tenerife, Spain. *The Getty Conservation Institute*.