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TESTING AND IMPLEMENTATION OF MICROCLIMATE STORAGE CONTAINERS

DANA K. SENGE

ABSTRACT

This article presents microclimate storage research recently conducted by conservators in the National Park Service (NPS) Intermountain Region Museum Services Program. Museum collections in the Intermountain Region encompass artwork, historic objects, prehistoric and historic archaeological objects, and natural history specimens. These collections contain metals that are subject to environmentally induced deterioration and plastics whose inherent deterioration can be slowed with environmental control. Microclimates have been used in various forms to protect these materials while in storage.

We have been reassessing microclimates currently used in the NPS Intermountain Region and researching improved methods. This has included reviewing microclimate storage methods used in museum collections throughout the United States, Canada, and Europe. Our research has examined: access to materials to create microclimates, ease of creation, ability to maintain a climate, ease of access to objects inside, and maintenance. This article summarizes our research and testing to date.

1. INTRODUCTION

The conservation and curation staff in the National Park Service (NPS) Intermountain Region Museum Services Program (IMR-MSP) at the Western Archeological and Conservation Center (WACC) in Tucson, Arizona, has identified significant numbers of actively corroding metals in storage at WACC and in several collections in parks in the region. Over several decades, the staff has worked with various preservation solutions for the collections in storage at WACC including item-level treatment, maintaining dry microclimates in cabinets, and using heat-sealed, vapor barrier bags to create small dry microclimates. These storage solutions have all provided some level of stability for the actively corroding metals; however, the solutions have not been fully successful for our program, either limiting accessibility or requiring monthly maintenance that staff did not have time to address. The effort to maintain the microclimates in cabinets was abandoned in the late 1990s, and many of the collections were sealed in Marvelseal vapor barrier bags.

In 2010, we began testing variations of microclimate storage solutions that could not only be useful in the repository at WACC but also with park museum collections throughout the region. Our goal was to create microclimate containers that could be easily constructed from affordable, easily accessible supplies and would maintain a stable environment with minimal maintenance. For actively deteriorating metals, the most desirable environment consists of relative humidity held below 15%; gradual fluctuations in this environment are acceptable. In addition, we hoped to improve object accessibility. Within a few months, we found a solution that was worth placing in a real-time test scenario. The results of the first year of real-time testing were so positive that the microclimate solution was implemented in the first park collection in 2012.

The results of the initial microclimate research inspired possible solutions for storage microclimates for plastic objects. Different environments are necessary for different plastics; some require pollutants to be removed from the storage environment, whereas others require a carefully sealed storage environment, and still others require low oxygen. Storage for different plastics is discussed further in section 5. During 2013, we began examining the condition and the needs of the plastics in storage at WACC. Current literature on preventive conservation of plastic objects was reviewed, and objects in the collection were individually surveyed to document condition and develop preservation recommendations. In addition, the survey included identification of plastic materials through visual cues and spot testing and weighing the objects to gather baseline data to monitor deterioration.

Existing literature for plastic storage has helpful guidance on environments that would slow the deterioration of various plastic materials, especially *Conservation of Plastics* by Yvonne Shashoua (2008). However, we did not find many practical solutions for creating those storage environments. As a result, we have begun testing a variety of options to create the recommended environments while maintaining some level of accessibility.

The following sections describe the testing and solutions developed for microclimate storage of metal objects and the testing underway for microclimate storage solutions for plastics.

2. METALS MICROCLIMATE BACKGROUND

The microclimate storage of archeological metals is not a new topic in objects conservation. Variations of storage solutions have been tested for years and are regularly refined on the basis of collection need and the availability of new products. A common storage box used in the United Kingdom is a polyethylene box with a *sandwich seal* closure containing a desiccant (Watkinson and Lewis 2005) often referred to as a Stewart box, the name of the box manufacturer. Newer solutions utilize a vapor barrier film, such as Marvelseal or Escal, to contain the objects and desiccant (Brown 2010). And most recently, testing of oxygen absorbers in the sealed environment was presented at the ICOM-CC Metals 2013 conference (Boccia Paterakis and Mariano 2013).

3. EXISTING METALS STORAGE

Museum collections at WACC are stored in a repository that has temperature held around 68°F and relative humidity (RH) held between 35 and 40%. Although the building experiences a few environmental spikes related to equipment failure or power outage every year, overall the repository maintains a very stable environment.

Large metal archeological objects are stored on open shelving and small archeological metal objects are currently stored in multiple ways:

1. in trays in cabinets,
2. in polyethylene zipper lock bags in cabinets,
3. double bagged in polyethylene bags, the object in the inner bag and packets of Desi-Pak desiccant and a humidity indicator card between the inner bag and the outer bag, or
4. groups of objects stored individually in polyethylene zipper lock bags sealed together in a vapor barrier bag with desiccant and a humidity indicator card.

Each of these storage solutions has drawbacks: either the storage environment is not dry enough to slow active corrosion, or the objects are very difficult to see and access.

4. TESTING NEW METAL MICROCLIMATE SOLUTIONS

4.1 INITIAL TESTS

The best sealed environment is created with a vapor barrier bag of Escal or Marvelseal (fig. 1). These materials, however, are often intimidating for people without conservation experience to use and maintain. In addition, our preferred material, Escal, is expensive. Our goal with these tests was to identify a second solution that could be easily implemented without a conservation team onsite, either at the repository at WACC or in a park.

Tests began by examining a wide range of lidded plastic containers selected on the basis of availability and ease of use. These included various brands of lidded polystyrene containers, polyethylene snap lid storage containers, and silicon gasket seal plastic food storage containers. These containers were placed inside a humidity chamber, and data loggers were used to monitor humidity inside the containers as well as inside the chamber. This allowed us to record the rate at which the humidity entered the containers (fig. 2).

There was a marked difference between containers with and without the silicon gasket in the lid. Although the RH rapidly increased in each container, the containers without gaskets had an increase of 65 percentage points over the course of 36 hours (fig. 3) and the containers with gaskets showed an increase of 7.5 percentage points over the same amount of time (fig. 4). Storage containers without a gasket seal were quickly ruled out.

In addition, the vapor-proof container design currently recommended for storing photographic materials in cold storage (Voellinger et al. 2009b) was tested. Although this box design maintains a steady environment, the fabrication includes placing a box inside three bag layers, taping each bag closed after it

Fig. 1. Example of an object in tray enclosed in Escal vapor barrier bag (Courtesy of Dana K. Senge)

Fig. 2. Humidity chamber with testing (Courtesy of Dana K. Senge)

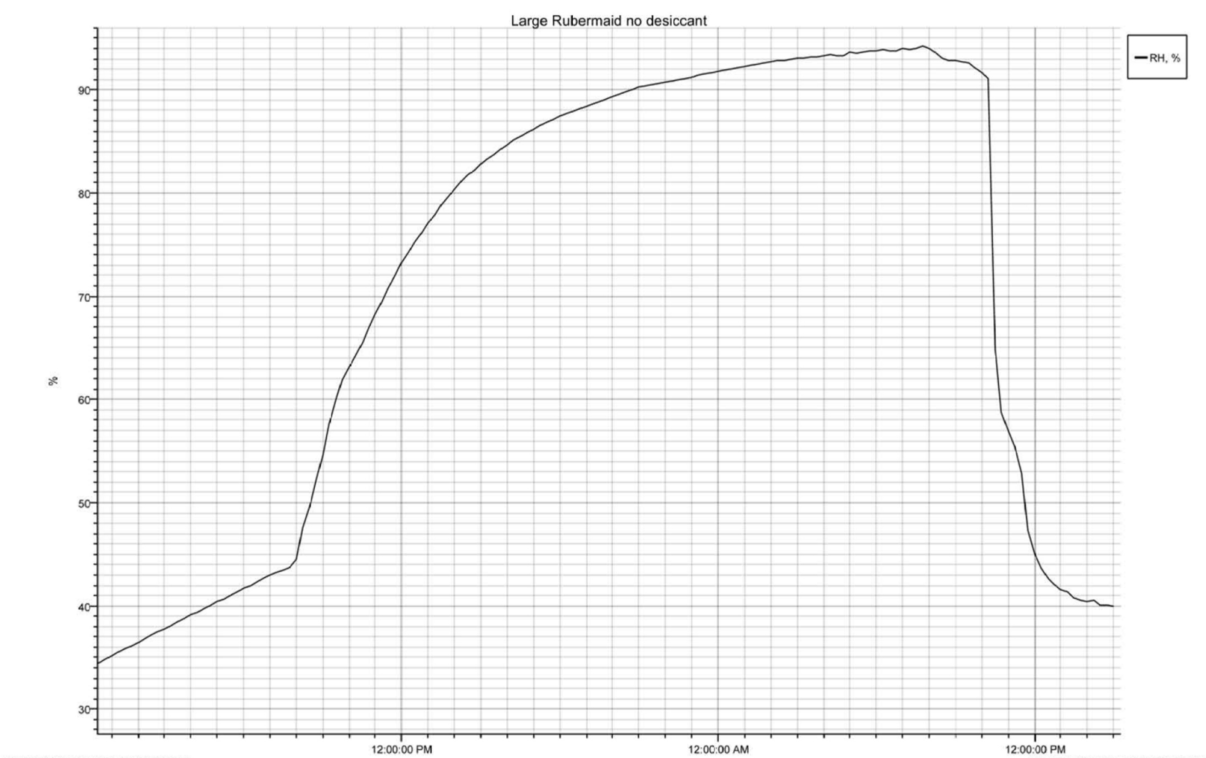

Fig. 3. Relative humidity of box without silicon gasket at closure. RH increases 65 percentage points over the course of one day.

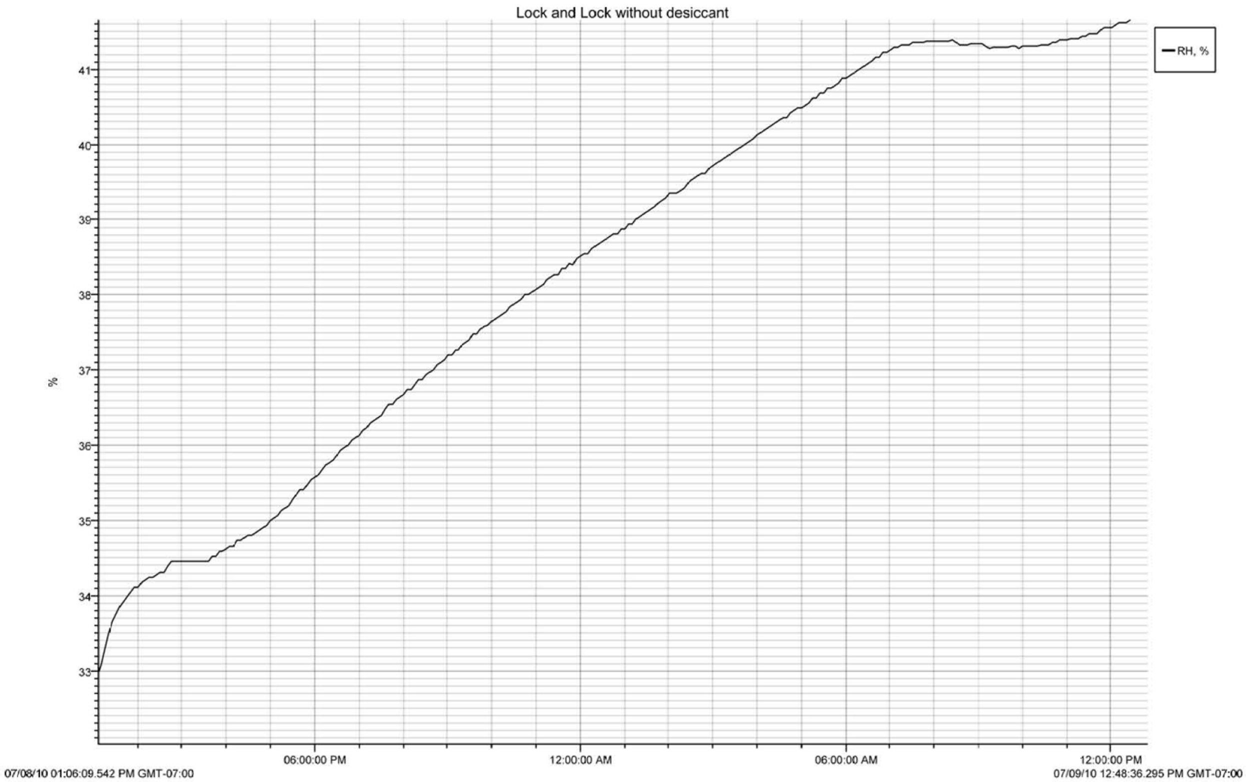

Fig. 4. Relative humidity of box with silicon gasket at closure. RH increases 7 percentage points over the course of one day.

has wrapped around the box. In the initial testing, we realized that enclosing the box required a lot of handling, which would place the objects potentially stored inside at significant risk from mechanical damage. As a result, we performed no further testing on this storage method.

The initial testing narrowed the box candidates to containers with silicon gasket in the lids, commonly used for food storage. We designed the next round of testing to observe the performance of the desiccant, which is needed to regulate the internal environment in the containers. Specifically, we wanted to know if the desiccant would be quickly exhausted. Packets of Desi-Pak desiccant and a data logger were placed in each test box, and the boxes placed back in the humidity chamber for up to a month. Each of the boxes tested held the RH steady for the testing period.

As the end of the initial tests, samples of the materials of these containers, the silicon and polyethylene, were Oddy tested. Metal coupons were also placed in a sample box and observed over the course of the year to determine if the plastic components were off-gassing any undesirable pollutants. None was detected through this period.

4.2 REAL TIME TESTING

To understand the limitations of these containers, sample boxes containing desiccant and data loggers were tested in three different storage environments for 1 year. One box was placed in our storage facility in Tucson, Arizona, a climate controlled space with RH around 35%, plus or minus 5%. The second was placed in an NPS storage facility in Montana that has minimal RH control, the RH in this environment gradually increases from 25% in the winter months to a high of 45% in the summer and gradually decreases again in the fall. The third was placed in an NPS storage facility in Texas, where the humidity is around 50%, plus or minus 5%, with spikes of higher humidity in during the summer months. For this test, the quantity of desiccant placed in the boxes was double the standard amount recommended (Weintraub 2002) to regulate the environment.

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

The data gathered during the first year showed the greatest increase in RH was in the test box stored in the most humid environment in Brownsville, Texas. The RH in this box only increased its RH by 2 percentage points (fig. 6). This minor increase was encouraging and the boxes were placed back into the test storage environments for a second year without changing or reconditioning the desiccant.

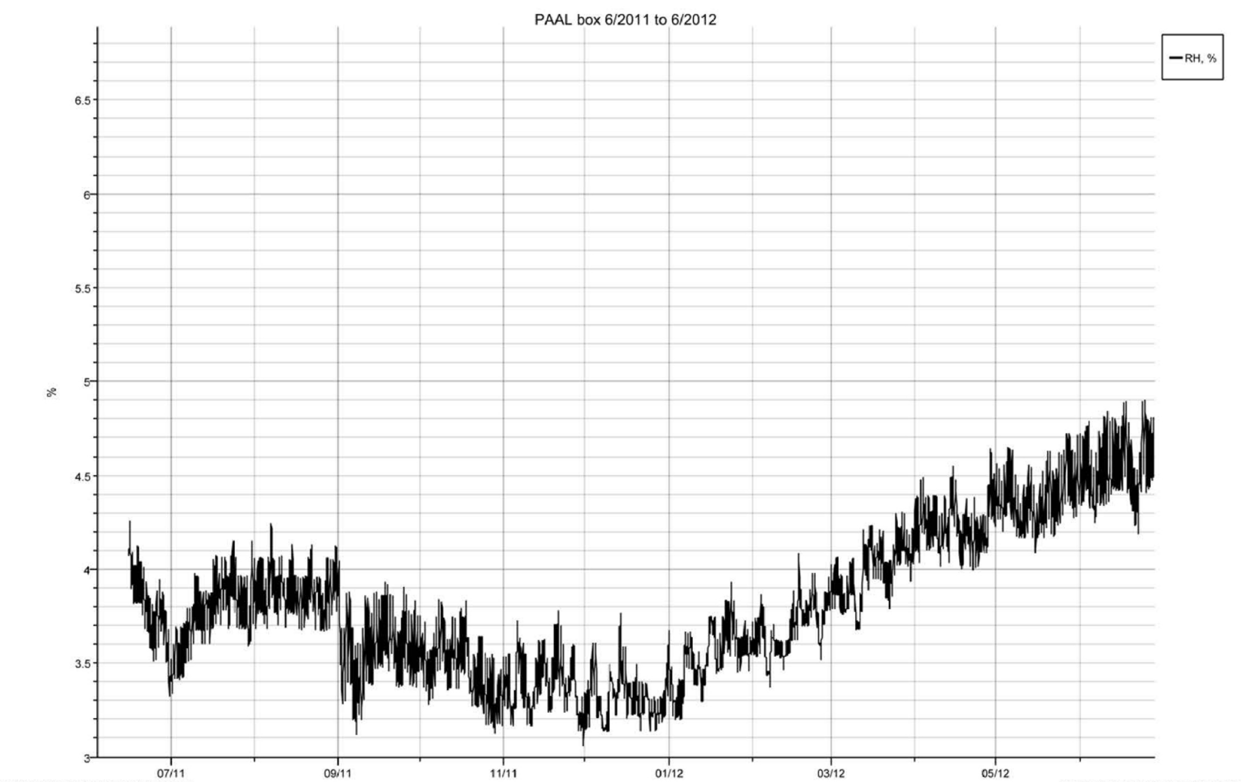

Fig. 6. RH data showing an increase of 2 percentage points over the course of the first year.

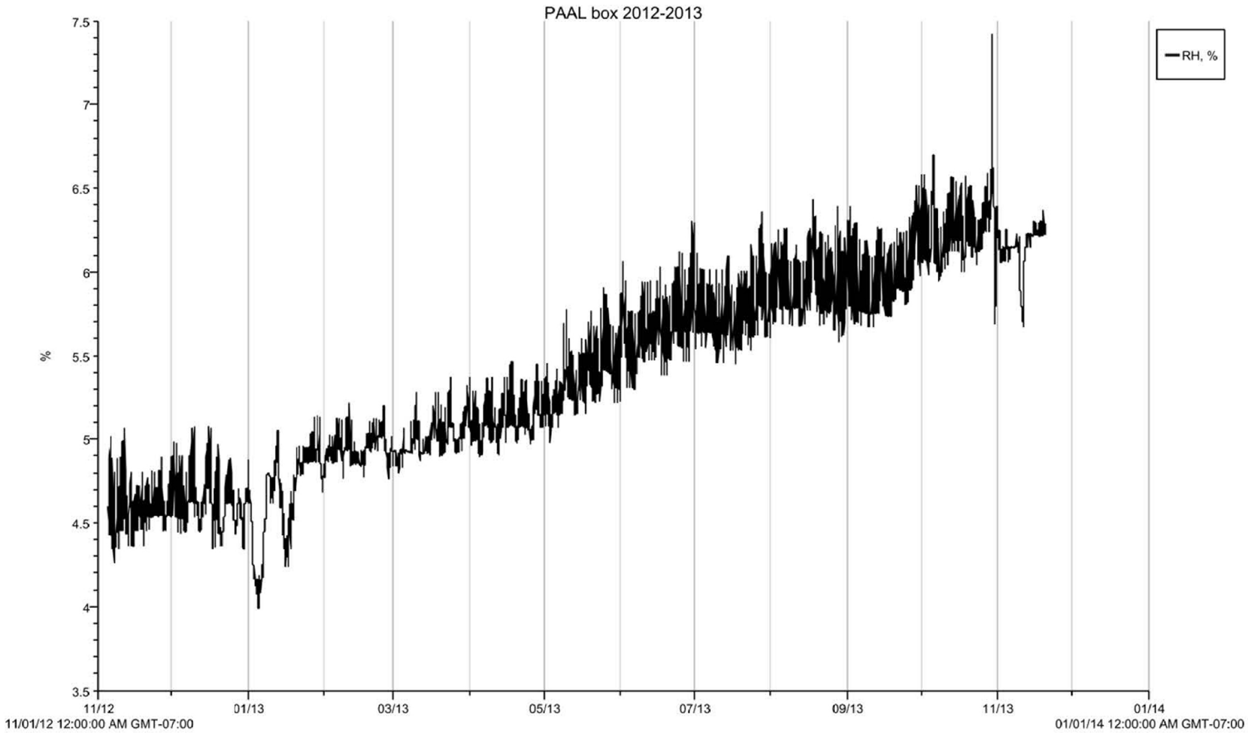

Fig. 7. RH data showing an increase of an additional 2 percentage points over the course of the second year.

The RH increase in the second year was very similar, rising another 2.7 percentage points (fig. 7). This rate of increase was acceptable to us, and on the basis of this testing, we estimate that to keep the RH under 15% in these containers, the desiccant will need to be changed every 5 years or so.

4.3 IMPLEMENTATION

After the positive results of the first year of real-time testing, an opportunity arose to implement the storage method for small metal objects in a single park's museum collection. This first collection had more than 7,600 of metal objects that were placed in over 200 microclimate storage containers.

Unfortunately, after a single year of storage, the RH in many of these boxes had risen from below 5% to over 15%. This was a surprising rate of increase in RH given the initial test results of an empty box gaining only 2 percentage points over the same time period. This increase in RH may be attributed to human error during box preparation, such as over exposing the desiccant to humidity during fabrication. A wide range of people were involved in the project, and it is plausible that human error played a role in the quick rate of RH increase.

The desiccant packets for this museum collection were changed in the summer of 2013 by a single staff member who paid attention to box closure and exposure of the desiccant packets. The boxes are currently being monitored quarterly to determine if the increase in RH observed in the first year was an anomaly, or if this experience is showing that new issues need to be addressed. Nine months after the desiccant was replaced, the boxes still maintain RH below 5%.

4.4 METALS MICROCLIMATES SUMMARY

The best container we found for creating metals microclimates is a polyethylene snap lid container. It is an accessible, reusable storage container that maintains a stable environment. Unconditioned desiccant, desiccant at or around 0% RH, is used to hold the environment below 15%

for as long as possible. As noted earlier, box preparation requires careful attention detail to ensure boxes are completely sealed when closed.

Product manufacturing and availability, of course, changes over time; thus, as new microclimate boxes are purchased, the materials are Oddy tested to ensure the containers do not off-gas products that may cause damage to museum collections.

5. PLASTIC MICROCLIMATES BACKGROUND

Current recommendations for storage of plastic objects vary by material type. Most plastics, especially cellulose nitrate and cellulose acetate, require an environment that removes pollutants, including the degradation products of the plastics themselves, from the surrounding environment. This is thought to slow the rate of deterioration by removing acids derived from the deterioration process and minimizing autocatalysis. The recommended storage environments focus on either ventilated storage or the use of pollutant scavengers in the storage environment (Shashoua 2008).

One exception to this guideline is the storage of rubber objects. Current research indicates that "the rates of crazing, crumbling and discoloration of natural rubber" (Shashoua 2008, 198) can be slowed in low-oxygen environments.

The other main exception to the general storage guidelines for plastics is storage for plasticized poly(vinyl chloride), PVC. Current research indicates that plasticized PVC objects deteriorate most severely by plasticizer migration, which is hastened by contact with materials which are adsorbent to these plasticizers. These materials include the most common materials used in museum collection storage: paper-based and polyethylene-based materials. Mylar (polyethylene terephthalate sheeting) and glass containers are currently the only recommended storage materials for these objects (Shashoua 2008).

Cold storage is commonly recommended for the preservation of plastic film materials (Shashoua 2008, Voellinger et al. 2009a), but has not been regularly implemented for 3D objects (Shashoua 2008). Cold storage is recommended as a possible solution for slowing deterioration, but there is a risk of condensation occurring during the cooling process of thick walled materials that may cause additional damage to the plastic (Shashoua 2008). Because variations in thickness are more likely found in 3D objects, this is a risk that should be considered.

6. EXISTING STORAGE

Plastic objects in storage at WACC are currently stored stacked in boxes, in single layers in cabinet drawers, and in trays on open shelving. The objects are commonly enclosed in polyethylene bags in each of these locations. For the most part, storage location is determined by ease of access for researchers rather than by material type and need; however, a small group of objects received storage upgrades on the basis of recommendations from a plastics survey in 1998. The objects identified as cellulose nitrate and cellulose acetate in this survey were placed in deep trays with Tyvek lids and are stored in an area where air flow is present (fig. 8).

7. PLASTIC MICROCLIMATE TESTS

Through the 2013 condition survey, we realized that existing storage is not fully successful in creating the recommended preservation environments for plastic objects. The majority of plastics in the collection were found to require storage that removes any off-gassing to slow deterioration. Existing storage in

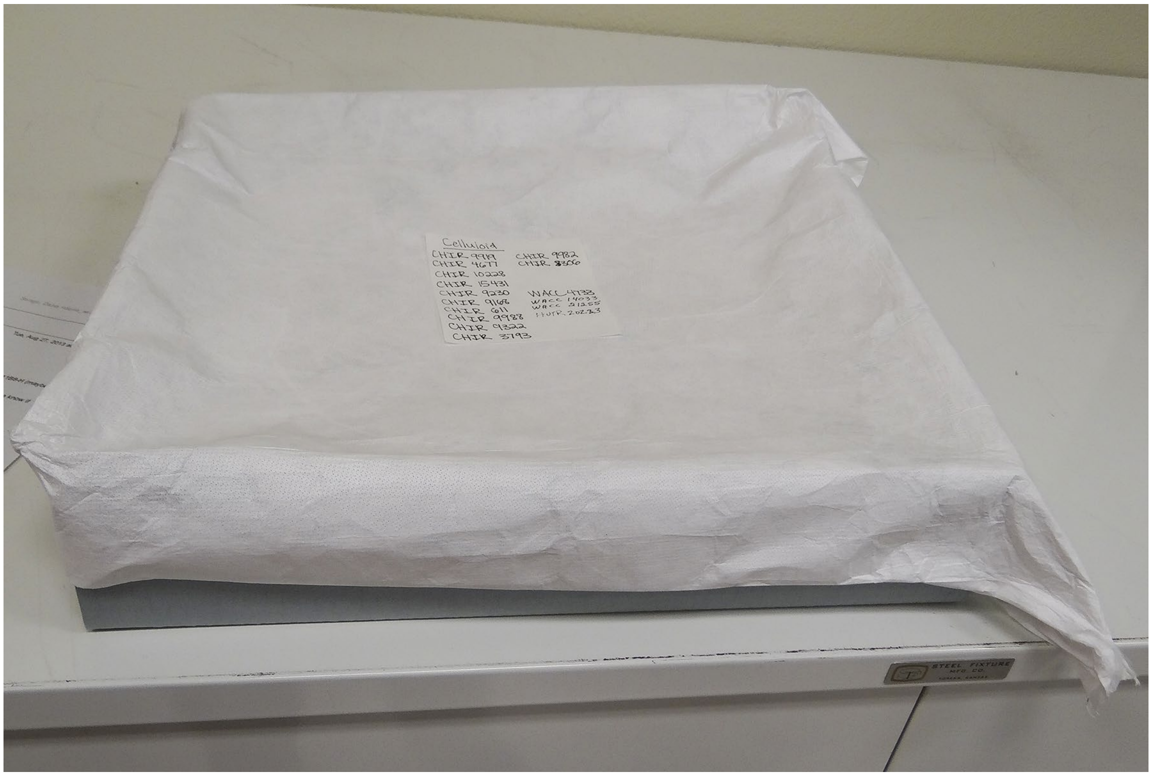

Fig. 8. Existing ventilated storage for cellulose nitrate and cellulose acetate objects (Courtesy of Dana K. Senge)

cabinets, in boxes, even in the trays with breathable lids, does not remove the deterioration products as needed. Currently there is no low-oxygen storage for rubber materials, and PVC objects are not fully enclosed in nonadsorbent materials as recommended in conservation literature.

The solutions we develop at WACC are likely to be implemented in other NPS museum collection storage repositories and, as with the microclimates for metal storage, need to be easy to construct, monitor, and maintain. The following sections describe our initial attempts to find practical solutions to create these recommended environments through ventilated storage, adsorbent storage, and low-oxygen storage solutions. Section 7.4 summarizes the storage solution technique we have begun to implement for plasticized PVC.

7.1 VENTILATED STORAGE TESTS

Ventilated storage is difficult to achieve in a dense storage space. In the existing storage repository at WACC, there are two main storage options: inside an enclosed cabinet or on shelves in compact shelving units. Cabinet storage obviously has no ventilation; however, several modifications were considered including using screen or grating on the front and back, which may permit more air flow. Unfortunately, in the WACC repository, cabinets are stored along the walls of the facility, a location with limited air flow regardless of how the cabinets may be modified.

The upper shelving of the end units of the compact storage system have decent air movement and was selected as a testing location for ventilated storage containers.

Another issue we needed to take under consideration for ventilated storage is potential dust accumulation on the objects. This is an especially important issue for plastic objects as dust can become affixed to the surface of degrading plastics, and removing it may cause additional damage.

Fig. 9. Initial ventilated storage box tests and shelf layout (Courtesy of Dana K. Senge)

7.1.1 Initial Testing of Ventilated Storage Options.

The initial tests were developed to understand dust accumulation of various box and lid combinations. Two box styles and three lid options were placed in the ventilated storage location. Double-stick tape mounted to glass microscope slides were placed in the boxes and in unprotected locations on the shelf to monitor dust accumulation. The boxes were staggered on the shelf to maximize airflow (fig. 9).

Two box variations were tested: boxes with openings in the walls that were covered with polyethylene window screen and boxes with slats cut into the walls. Three lid variations were tested: no lid, a Hollytex fabric lid, and a solid acid-free corrugated board lid.

The boxes were left in this storage location for four weeks and then the tape and the microscope slides visually examined for dust accumulation. As expected, the slides placed in unprotected locations on the shelf had the most dust accumulation. The slides in containers without lids had the next most dust accumulation. The slides in each of the lidded containers had very little to no dust accumulation. This initial test indicated to us that dust accumulation was minimal regardless of lid or wall style.

Because of the ease of creating the screened wall versus the cut slat wall, the screened wall boxes were selected for further testing of ventilated storage.

7.1.2 Testing Acid Vapor Buildup in Ventilated Storage

Actively deteriorating cellulose acetate objects and A-D test strips were selected to test acid vapor buildup in both ventilated storage and the adsorbent storage tests described in section 7.2.

The cellulose acetate objects selected are shower curtain rings from Chiricahua National Monument. These were determined to be actively deteriorating because the smell of acetic acid would build up in their storage container over the course of just a few hours, a common indicator of the deterioration of cellulose acetate. This object group is ideal because it has multiple components that are similar in size, age, and deterioration. An A-D Strip (acid-detecting strip), manufactured by the Image Permanence Institute, was placed in the shower curtain ring storage box for 24 hours at room temperature and 30% RH. The A-D strip shifted from deep blue to a marine blue or deep blue green. This is between 0 and 1 on the A-D strip scale, indicating deterioration is just beginning.

A-D strips from the Image Permanence Institute were selected to help monitor the buildup of acids in the test environments. The A-D strips are a diagnostic tool to determine how much acid is released by film in an enclosed space over a specific amount of time at a determined temperature and RH. While our use of these strips as an indicator of acid trapped in an environment is not the official intended

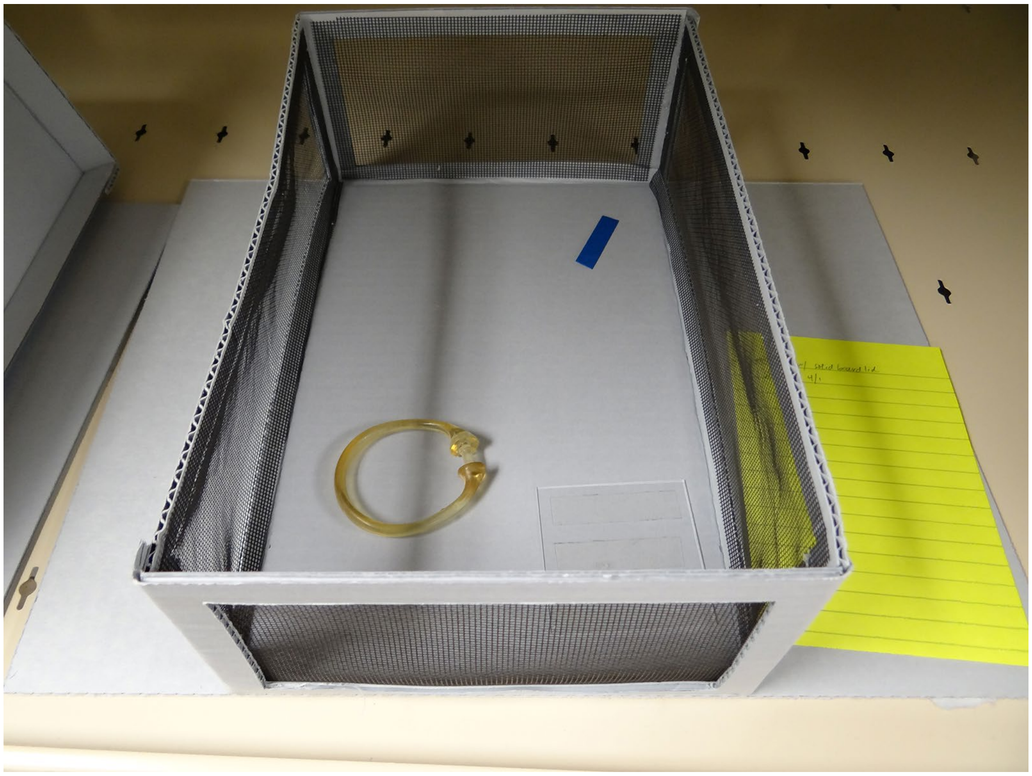

Fig. 10. Contents inside ventilated test storage (Courtesy of Dana K. Senge)

use, we believe that they are a good indicator of the effectiveness of the test environments. Product literature indicates that longer exposures may not give an accurate account of object condition. Because our use in this scenario is not to monitor object condition but, instead, the possible increase of acidic gases in a given environment, we believe these strips are good general indicators.

Two screened wall boxes, one with a Hollytex fabric lid and one with an acid-free corrugated board lid, were set up in the ventilated storage test location in the collections repository. Each contained an individual curtain ring, an A-D strip, and the double-stick tape on the microscope slide to continue monitoring dust accumulation (figs. 10, 11).

Fig. 11. Two test boxes on shelf (Courtesy of Dana K. Senge)

After eight weeks of testing, the A-D strips in the test containers remained their original dark blue color, indicating that there was no buildup of acidic vapor in the containers. Given that the existing storage container for the shower curtain rings shows a buildup of acidic vapor in only a few hours, the results of the initial tests are very promising for improved ventilated storage. A small amount of dust has accumulated on the glass slide in the box with the Hollytex fabric lid, reducing the desirability of this environment for long-term storage.

Our next round of testing will be to increase the quantity of actively deteriorating objects in the test environment. In addition, we are considering how the pollutants released from the plastics may affect the objects stored in surrounding areas.

7.2 ADSORBENT STORAGE TESTS

Although ventilated storage may be a good option in some locations, the use of adsorbents, such as activated carbon or zeolites, in a sealed environment is another way to remove gaseous pollutants from the storage environment and may permit denser storage of museum objects than the ventilated storage solution.

The polyethylene storage containers with silicon gasket seals identified in the testing for microclimate storage of metals were used to test the effectiveness of a microclimate containing an adsorbent or pollutant scavenger. Six test boxes were created to test the effectiveness of four adsorbents against a control (fig. 12).

The adsorbents tested were: Getter Pak activated carbon packets, Zorflex activated carbon cloth, Kodak molecular sieve packets, ArtCare museum mat board with microchamber technology.

The test boxes that were calculated hold 168 in.^{3} of volume. Determining the quantity of adsorbent to use in a specific volume of air is difficult; comparing products to each other is even more

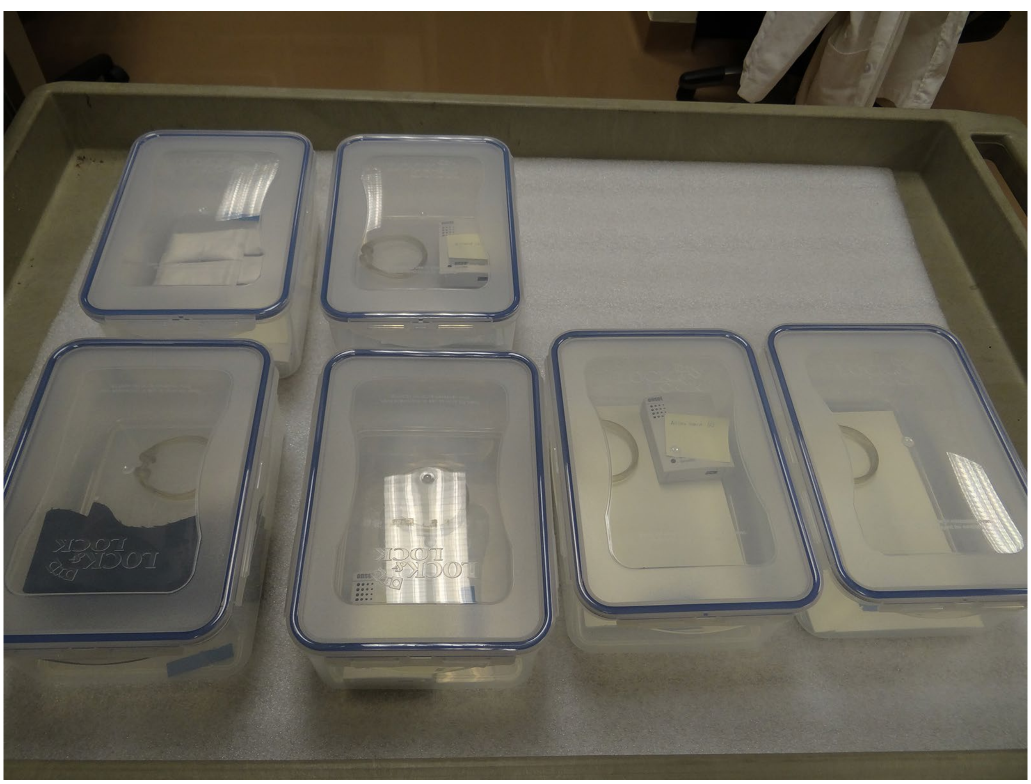

Fig. 12. Adsorbent microclimate test boxes (Courtesy of Dana K. Senge)

difficult. Because the type of pollutants and quantity of pollutants present in a given volume of air vary, many of the companies that manufacture adsorbents do not test their products in a way that would tell how much to use for a given volume for a period of time. We used available product information and direct phone calls with the companies to help guide us in determining quantity of adsorbents to the microclimate boxes.

The Getter Pak activated carbon packets are listed on the supplier website (see Sources of Materials) as odor-adsorbing packets. The 2 g packets are listed as protecting 45 $in.^3$ of space. Four 2 g packets (8 g) of the Getter Pak were placed in the microclimate test box for the initial tests.

The Zorflex product information states that 1 g of the activated carbon cloth has the internal surface area of over half the size of a football pitch (Chemviron Carbon 2014). There is no comparable data to the Getter Pak product. For the initial tests, we elected to use the same weight of each activated carbon product to see what variation would occur between the two; therefore, 8 g Zorflex activated carbon cloth was used in the test microclimate box. Because the weight of Zorflex includes the weight of the cloth, it is possible that 8 g of Zorflex activated carbon cloth has less activated carbon than 8 g of Getter Pak activated carbon packets.

The Kodak molecular sieve packets were specifically developed to protect cellulose acetate film in a film canister. Because of this narrow range of use, the product has recommended quantities for a specific volume: Kodak recommends the use of three 12.5 g molecular sieves in a film canister that holds 1000 ft. of film (Kodak 2014). The film canisters of this size tend to be approximately 11 in. in diameter and 2 in. deep, creating 190 $in.^3$ of volume. Three molecular sieve packets were placed in the initial test container.

The ArtCare board manufactured by Nelson Bainbridge has no product information that provides how much of the adsorbent is present in the board or how much board to use in a given space. Phone conversations with representatives of the company did not provide insight into determining how much board to use in a given volume of space. Two test boxes were made to monitor the variation that may occur between two different quantities of this product, a single piece of 4.75 × 7 in. 4-ply ArtCare board was placed in one box, and two 4.75 in. × 7 in. pieces of the 4-ply ArtCare board were placed in the second box.

The adsorbents were placed in the microclimate boxes with a cellulose acetate shower curtain ring and an A-D strip. The control box contained only a shower curtain ring and an A-D strip. Digital data loggers were placed in four of the test boxes: the control, the Getter Pak activate carbon packets, the Kodak molecular sieve box, and the box containing two sections of ArtCare board to monitor any desiccating effects the adsorbents might have on the enclosed environments.

Within a month, the A-D strips in each test container detected the presence of acidic vapors. The A-D strip in the control box (with no adsorbent) began to shift color from dark to marine blue within 24 hours. The A-D strip in the box containing Kodak molecular sieves began to shift color within the first 5 days; the strip in the box with one piece of ArtCare board began to shift within the 8 days; the strip in box containing the Getter Pak activated carbon packets also began to shift within 8 days; the strip in the box with two pieces of ArtCare board began to shift at 11 days; and the A-D strip in the box containing the activated carbon cloth was the last to begin color shifting, after 18 days.

After the first 3 weeks of testing, the A-D strip in the control box had shifted color to bright green, two on the A-D strip scale, and the object was removed from the control test box due to concern that the increase in concentrated pollutants would trigger an increased rate of deterioration in this object by exposing it to a concentrated volume of pollutants.

The environmental data showed that each adsorbent lowered the RH of the climate to a certain extent. The ArtCare board and the Getter Pak immediately lowered the RH in the climate from 38 to 20% RH; however, over the course of the month the RH crept up toward 26% RH in each container. The Kodak molecular sieves lowered the RH to approximate 0% RH. The first month of data shows some spikes in the middle of the month, up to 12%, which may be associated with opening the container temporarily.

The second round of tests for the adsorbent products began on May 1, 2014. In this round of testing, quantities of adsorbent materials were doubled to determine if quantity of adsorbent would slow the rate of color shift in the A-D strip. During this second month of testing, the test strips shifted color at rates similar to that in the first month, with the exception of the activated carbon cloth, which did not shift color in the 30-day period.

Testing continues, the next test will be to place a larger quantity of the deteriorating cellulose acetate objects in the test environments, and our goal is to determine if one or two adsorbent products can be tested over the course of a 12-month period to being understanding the longevity of the pollutant scavengers and the viability of monitoring over the long term with the A-D strips. We continue to look into other pollutant monitoring solutions. At the same time, we are considering a maintenance program that replaces the adsorbent on a cyclic basis, likely starting at an annual cycle.

7.3 LOW OXYGEN STORAGE TEST

Low oxygen environments can be created with an oxygen scavenger, such as Ageless or Oxy-Guard enclosed in a vapor barrier film such as Escal or Marvelseal that is closed by heat-sealing.

Although good storage containers can be created with trays enclosed in a vapor barrier film, we want to fully investigate the possibility of using containers that are easier to open and close. The main goal of testing other options is to understand if a rigid container can withstand the pressure of the reduction of 20% of the air volume in a container with the oxygen removed, and the general rate that oxygen enters a storage container with a silicon gasket lid.

The first test was set up using the polyethylene box with a silicon gasket in the lid as the container rather than the vapor barrier bag. The container held a ZerO2 Alert indicator and ten times the quantity of Ageless needed to remove oxygen from the volume of the box. Oxygen was removed from the container within 1 day and a low-oxygen environment was held for 21 days. The second test has begun with a similar style container with a glass body to understand if the variation in material type will have a major influence on the rate of oxygen flow into the container.

Monitoring multiple storage environments with the ZerO2 Alert indicator is not a practical solution; an individual monitor is over $500 at this time, and takes up a significant amount of space in the storage environment. The Ageless Eye Oxygen Indicator has been used as a monitoring tool in the past, but it is becoming more difficult to find because of its short shelf life and inconsistent behavior when placed in a long-term monitoring situation. A possible replacement is the Tell-Tab Oxygen Indicator by SorbentSystems, which will be tested in 2014 and 2015. Another solution under consideration for monitoring the presence of oxygen is an optical oxygen sensor. This equipment utilizes a sensor inside the storage container and uses a fiber optic probe to read the sensor (Matthiesen 2007). Although more expensive than the ZerO2 Alert indicator, this equipment has the flexibility to check multiple environments.

Unfortunately the overarching goal of creating microclimates that are easy to prepare, maintain, and access is limited in this circumstance. At this time, low-oxygen microclimates can only be created at WACC and maintained by the conservation staff.

7.4 STORAGE OF PLASTICIZED PVC OBJECTS

Published recommendations for PVC include enclosing in glass or Mylar, and excluding other plastics or paper-based materials that might absorb the degradation products (Shashoua 2008). Storage improvements have begun on the basis of these recommendations; Mylar was selected as the more desirable storage material given its flexibility and durability. Objects have been enclosed in 1-mil Mylar

Fig. 13. Plasticized PVC object enclosed in sealed Mylar and set on a handling tray. National Park Service, Chiricahua National Monument, CHIR 6875 (Courtesy of Maggie Hill-Kipling)

packages that are closed with a single-impulse heat sealer. The sealed object is then placed on a support tray (fig. 13).

7.5 PLASTIC MICROCLIMATE SUMMARY

Our testing is not complete, but we have learned a great deal about possible solutions to store the plastic collections at WACC. As our testing continues, we have narrowed our focus to one or two solutions to provide ventilated or adsorbent storage environments and are observing how the containers perform with greater quantities of objects contained inside. Our concern about the pollutants released from plastics stored in ventilated storage causing damage to nearby objects may be easily resolved by placing the plastics near materials inert to the acids that they release; for example, storing plastics near ceramics and glass. We continue to look for options to monitor low-oxygen storage. These include inexpensive solutions such as the Tell-Tab Oxygen Indicator detection tablets as well as more expensive solutions such as an optical oxygen sensor. And, as discussed in section 7.4, published recommendations for PVC storage have proved simple to develop and implement.

8. SUMMARY

Developing microclimates for metals and plastics is an ongoing cycle of learning and testing, implementing, and testing again. We have made progress in understanding what containers create well-sealed environments, and we are beginning to understand ways to use these environments and various scavengers to create storage for various materials in our specific repository. In a few situations, we are developing solutions that are fairly basic to use; however, some, such as low oxygen environments, require more experience to create and maintain.

With metals, we have the flexibility to suggest to a park that all of their small metals be stored in the low RH environments, and we expect little to no harm to come to those objects. With plastics, more upfront investigation has to occur before we can advise specific climate type. In some situations, we may have to create the climates and then advise the park staff how to maintain them, or suggest that those items be stored in Tucson where we can provide cyclic maintenance for the objects.

Recognizably all of these microclimates will fail with time, can fail with human error, and require cyclic attention. We continue to research better options for monitoring the environments for storing plastics. We are, however, able to create effective environments by replacing adsorbents at regular intervals.

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SOURCES OF MATERIALS

Ageless Oxygen Absorber; Escal; ZerO2 Alert indicator
Keepsafe Microclimate Systems
9 Oneida Avenue
Toronto, ON Canada M5J 2E2
800-683-4696
www.keepsafe.ca

ArtCare Microchamber Board; Marvelseal; Mylar (1-mil); Zorflex Activated Carbon Cloth
Talas
330 Morgan Ave
Brooklyn, NY 11211
212-219-0770
www.talasonline.com

Desi-Pak (Manufactured by Süd Chemie)
The Rust Store
8376 Murphy DrMiddleton, WI 53562
877-256-9301
www.theruststore.com

Double Impulse Heat Sealer, AIE610FDA Dual 24 Sealerlothg. McCabe AIC. 9:169–194.
American International Electric
1325 S. Johnson Dr.
City of Industry, CA 91745
626-333-0880
www.aieco.com

Hefty Clip Fresh gasket seal containers (discounted rate for bulk orders)
Heritage Mint
PO Box 13750
Scottsdale, AZ 85267-3750
480-624-2422
www.HeftyFoodContainers.com

Humidity indicator cards (#S-8027); Getter Pak activated carbon packets (#S-20194); Oxy-guard (S-19586); Single Impulse Heat Sealer
Uline
12575 Uline Drive
Pleasant Prairie, WI 53158
800-295-5510
www.uline.com

Kodak Molecular Sieves
Spectra Film and Video
5626 Vineland Ave
North Hollywood, CA 91601
818-762-4545
www.spectrafilmandvideo.com

Tell-Tab Oxygen Indicator
SorbentSystems
13700 S. Broadway
Los Angeles, CA 90061
310-715-6600
www.sorbentsystems.com

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