

OBJECTS SPECIALTY GROUP POSTPRINTS 1991

ALBUQUERQUE, NEW MEXICO

VOLUME ONE



*THE AMERICAN INSTITUTE FOR CONSERVATION OF
HISTORIC AND ARTISTIC WORKS*

OBJECTS SPECIALTY GROUP

POSTPRINTS

1991

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Papers and presentations made at the annual meeting of the Objects Specialty Group of The American Institute for Conservation of Historic and Artistic Works, Albuquerque, New Mexico; June 8, 1991. Produced by the Objects Specialty Group; compiled by Pamela Hatchfield. ©All rights reserved by individual authors; 1992.

IN MEMORIAM

This first volume of the
Objects Specialty Group Postprints
is dedicated to the memory of
our friend and colleague

Jane Carpenter Poliquin

FOREWORD

This is the Object Specialty Group's first volume of *Postprints*. They were initiated in an effort towards greater communication with our colleagues, in hopes that our willingness to exchange information, techniques and experiences would promote the collective growth of knowledge and professionalism in our field. The *OSG Postprints* were created partly because the presentations in our meeting this year formed a cohesive body of material on environmental issues. They are also the reflection of the modification of our annual meeting, which allowed us time to talk to each other this year in informal discussion groups. The need to document this part of our meeting was clear, and we hope our colleagues unable to attend the meeting in Albuquerque will benefit from our discussions by the dissemination of this information.

The *OSG Postprints* is a non-juried compilation. Papers and notes are printed as they were received from the authors. Authors are encouraged to submit entries presented here for publication in the *Journal of the American Institute for Conservation of Historic and Artistic Works* or in other juried publications. We recognize the fact that not all the information we find valuable and interesting lends itself to formal presentation or publication; these *Postprints* are intended to reflect the diversity of information and format we have incorporated into our meeting, and it is our hope that they remain rather informal and all-inclusive.

I would like to thank all the contributors to this volume for their participation. Special thanks are due to the coordinators of the small discussion groups, Jerry Podany, Bettina Raphael, Scott Odell, Ginny Naudé and Brian Considine, who set the tone for our first experience of controlled mayhem, and to Jerry, Ginny and Brian for providing summaries of their groups' discussions.

Pamela Hatchfield
OSG Chair

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THE EFFECTS OF GAS PHASE FORMALDEHYDE ON SELECTED INORGANIC MATERIALS FOUND IN MUSEUMS

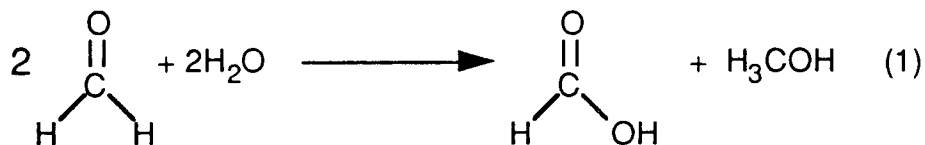
Mary F. Striegel*

ABSTRACT

This paper presents the preliminary findings of a study on the potential damage of formaldehyde air pollution on inorganic materials similar to those found in museum collections. Glasses, ceramic glazes, shells and metals were exposed to 1200 parts per billion (ppb) of gas phase formaldehyde for 30, 60, and 100 day time intervals. Damage to materials was evaluated on the basis of changes in visual appearance after exposure to formaldehyde. Evidence of surface change was documented using optical microscopy, scanning electron microscopy, and color measurement.

INTRODUCTION

Inorganic materials stored or displayed in museums may not be spared from the ravages of time. Pollutants within museums, such as acidic vapors or aldehydes released from wood and wood products, create corrosive environments which may damage inorganic objects (Hatchfield and Carpenter, 1987). Formaldehyde, which is found in museum environments, belongs to a class of chemicals known as aldehydes, and is characterized as having a hydrogen adjacent to a carbonyl group. Formaldehyde is a reducing agent. It can be oxidized to formic acid in the presence of water. This reaction (1), known as the Canizarro reaction, can be catalyzed on metal surfaces (March, 1977).



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Sources for formaldehyde include resins, wood products, particle board, plywood, construction materials, and combustion products (Committee on Aldehydes, 1981).

Information is needed on the potential for damage by indoor pollutants to museum collections. In order to answer this question, the Environmental Monitoring Program at The Getty Conservation Institute was designed. Seventeen institutions participated in the survey of indoor generated airborne pollutants including acetic acid, formic acid, formaldehyde and acetaldehyde (C. Druzik, Stulik, and Preusser, 1990)). The survey measured 183 individual sites within these institutions (galleries, storage areas and display cases). Concentrations of formaldehyde in museum environments range from less than 0.2 parts per billion to 1500 parts per billion. The question then became "what is the potential for damage to objects at these concentrations of pollutants ?" This study was designed to answer this question by exposing inorganic materials to gas phase formaldehyde.

EXPERIMENTAL

Samples

Replicate samples of all selected materials, including glasses, ceramic glazes, shells, and metals, were exposed to 1200 ppb of formaldehyde gas at a 30, 60, and 100 day time intervals. Two exposure samples and one control sample were investigated at each of the time intervals. The materials studied are listed in Tables 1A-1D.

Sample Preparation

Eighty-one metal samples were prepared from nine different metal alloys, including copper, brass, bronze, silver, sterling silver, iron, tin, lead, and zinc. Most metals were cut into one inch squares, then mounted to glass slides and polished to a 0.25 micron finish. Tin and lead samples were ground to a 600 grit finish. Samples were then cleaned ultrasonically, rinsed with methanol, and dried in a cool air stream. After polishing, samples were stored in containers with desiccant and activated carbon.

Thirty-six stained glass samples were prepared from red, green, blue and yellow glass. One inch squares were cut by hand from plate glass supplied by a local stained glass supplier. Each sample was rinsed with methanol and dried in a cool air stream.

TABLE 1A. MATERIALS STUDIED: GLASS.

GLASS	COMPOSITION
Green	Cu , Cr
Blue	Cu , Co
Red	Zn , Cd
Yellow	Ca , Mn

All glass was commercially available stained glass. Elemental composition was determined using X-ray fluorescence analysis. Elements in bold indicate major components, while plain text indicate minor components.

TABLE 1B. MATERIALS STUDIED: SHELL.

SHELL	COMPOSITION
Nautilus	CaCO₃
Mexican Beige	CaCO₃
Mexican White	CaCO₃
Abalone	CaCO₃

The shells were not chemically analyzed; the composition indicated is the nominal composition for sea shells. Minor and trace elements were not determined.

TABLE 1C. MATERIALS STUDIED: CERAMIC GLAZE.

CERAMIC GLAZE	COMPOSITION
Green	Cu , Pb , Ca , Si , S
Blue	Si , Pb , Co , S , K
White	Si , Al , Mg , Ca
Black	Si , Cr , Fe , Pb , Ca , S , K , <i>Mn</i> , <i>Ni</i> , <i>Cu</i> , <i>Cd</i>

Commercially available glazed ceramic tiles were obtained for this study. The composition was determined by energy-dispersive spectroscopy (EDS) on an Electroscan environmental scanning electron microscope (ESEM) using a Link Analytical system. Elements in bold indicate major components, plain text indicate minor components, and italics indicate trace components.

TABLE 1D. MATERIALS STUDIED: METALS AND ALLOYS.

ALLOY	COMPOSITION
Copper	99.9% Cu
Brass	70% Cu , 30% Zn
Bronze (cast)	85% Cu , 5% Sn , 5% Zn , 5% Pb
Silver	99.99% Ag
Sterling Silver	95% Ag , 5% Cu
Lead	99.99% Pb
Tin	98.8% Sn
Zinc	99.7% Zn
Iron	99.5% Fe

Composition for alloys given as nominal composition by supplier. The composition of bronze was verified using quantitative X-ray fluorescence Analysis.

Thirty-six glazed ceramic samples were cut from four different glazed ceramic tiles. Each two inch ceramic tile was cut into nine samples using a slow speed diamond saw. Samples then were rinsed with methanol and dried in a cool air stream.

Thirty-six samples of four types of seashells were selected and prepared for the formaldehyde exposure studies. These included Mexican white shells, Mexican beige shells, green nautilus shells, and abalone. The shells were prepared in the same manner as the ceramic tiles.

All samples were assigned a designation number which was then mechanically or hand engraved into the sample. The choice of control and exposure samples and time interval for each material was randomized by drawing lots. The samples were then placed in numbered locations in one of the chambers using randomly generated number tables.

Experimental Conditions

The samples were exposed under conditions similar to those found in actual museum environments. Conditions for this study are given in Table 2. Target conditions selected were 50% relative humidity (RH), ambient temperature, and 1200 ppb formaldehyde in a dynamic system with a flow rate of 0.5 liters per minute.

The formaldehyde concentration was generated using a permeation device consisting of paraformaldehyde in a semi-permeable membrane. The permeation device was placed inside a glass U-tube in a warmed oven, and attached to the exposure flow system (Figure 1). Laboratory air was first cleaned and dried through a series of purification cartridges. The air stream was then split into two portions, one which was supplied to the permeation device and a second which was humidified. The humidified air stream was then split a second time -- one portion supplied cleaned, humidified air to the control chamber, the second was mixed with the formaldehyde air stream in a Teflon mixing chamber. From the mixing chamber, the formaldehyde air stream was passed through the exposure chamber, then cleaned with activated carbon, and finally exhausted. The experimental parameters of flow rate and oven temperature were adjusted until the monitored formaldehyde concentrations (determined by HPLC methods (C. Druzik and Taketomo, 1988)) were approximately 1000 ppb formaldehyde at the inlet and outlet of the exposure chamber.

The formaldehyde concentrations were monitored throughout the 100 day exposure at both the inlet and the outlet of the exposure chamber, as well as at the outlet of the control chamber. Concentrations were monitored on a daily

TABLE 2. EXPERIMENTAL CONDITIONS.

The following conditions were controlled and monitored throughout the 100 day exposure:

CONDITION	UNIT	MONITORING PERIOD
Relative Humidity	$50 \pm 5\%$ R.H.	20 min
Temperature	$25 \pm 4\%$ °C	20 min
Formaldehyde	1.2 ppm	daily 1st week; weekly
Flow rate	0.5 L/min	

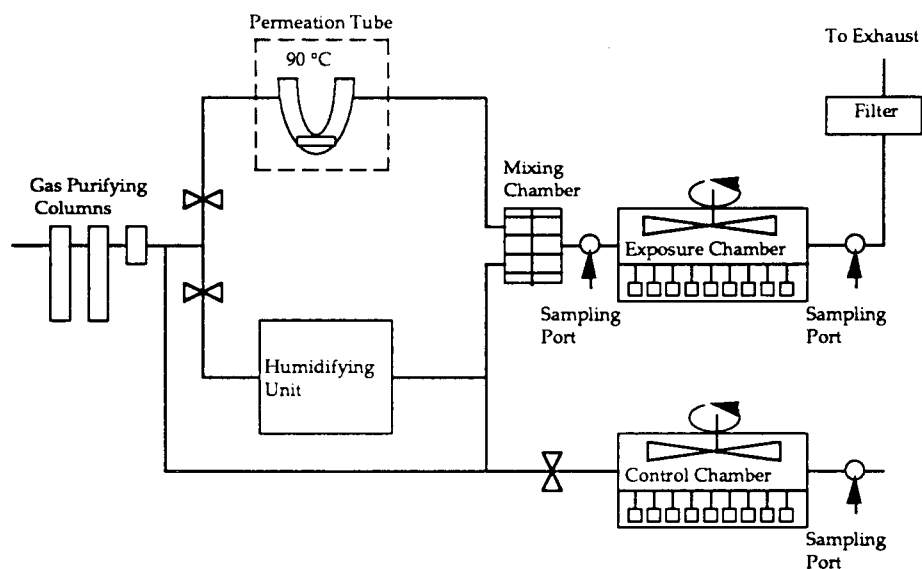


FIGURE 1. Schematic diagram of dynamic exposure system. Components include gas purification, permeation system, humidifying system, exposure chamber and control chamber.

basis for the first week of the exposure and weekly thereafter. Temperature and RH were monitored in 20 minute intervals throughout the experiment in the exposure and control chambers.

Instrumentation

Samples were investigated with one or more of the following techniques:

Light Microscopy: All samples were examined after exposure by light microscopy using a Nikon Epiphot metallurgical microscope system. Samples which indicated an initial difference from the control sample of the same material and time interval were documented with bright field and dark field illumination.

Environmental scanning electron microscopy: Sample morphology and composition was investigated using an Electroscan environmental scanning electron microscope (ESEM) equipped with a Link Analytical Energy-dispersive spectroscopy system.

X-ray fluorescence Analysis: Initial compositions of some materials were verified using a Kevex 0750A secondary target X-ray fluorescence Spectrometer.

Color Measurements: Color measurements of glass and ceramic glazes were performed using a Minolta CR121 chromometer to support visual examination of samples. Four measurements were taken at corners of each sample both before and after exposure. Data was recorded in CIE-LAB units, and ΔE was calculated between pre- and post-exposure measurements. A series of standard color tiles were measured before and after each series of measurements on the samples in order to monitor any instrumental shifts.

RESULTS AND DISCUSSION

After each exposure or control interval, all sample types were examined for evidence of change in surface appearance. Potential damage was assessed on the basis of change in visual appearance as evidenced by optical microscopy, color measurement, or electron microscopy. The results are given in Tables 3A-3D.

Glasses

Two exposure samples and one control sample for each of the red, blue, green and yellow commercially available stained glasses were examined by optical

TABLE 3A.** RESULTS: GLASSES EXPOSED TO
1200 ppb FORMALDEHYDE GAS

GLASS	30 DAYS	60 DAYS	100 DAYS
Green	No	No	No
Blue	No	No	No
Red	No	No	No
Yellow	No	No	No

Evidence of surface changes observed by optical microscopy.

TABLE 3B.** RESULTS: SHELLS EXPOSED TO
1200 ppb FORMALDEHYDE GAS

SHELL	30 DAYS	60 DAYS	100 DAYS
Nautilus	No	??	??
Mexican Beige	No	No	No
Mexican White	No	No	No
Abalone	No	??	??

Evidence of surface changes observed by optical microscopy and scanning electron microscopy.

TABLE 3C.** RESULTS: CERAMIC GLAZES EXPOSED TO
1200 ppb FORMALDEHYDE GAS

GLAZE	30 DAYS	60 DAYS	100 DAYS
Green	No	No	No
Blue	No	No	No
White	No	No	No
Black	No	No	No

Evidence of surface changes observed by optical microscopy and color measurement.

TABLE 3D.** RESULTS: METAL ALLOYS EXPOSED TO
1200 ppb FORMALDEHYDE GAS

ALLOY	30 DAYS	60 DAYS	100 DAYS
Copper	No	Yes	Yes
Brass	Yes	Yes	Yes
Bronze	Yes	Yes	Yes
Silver	??	??	Yes
Sterling Silver	No	Yes	Yes
Lead	Yes	Yes	Yes
Tin	??	??	??
Zinc	Yes	Yes	Yes
Iron	??	??	??

Evidence of surface changes observed by Optical microscopy and scanning electron microscopy.

** The criteria for entry into TABLE 3 is as follows: Yes = both exposed samples show a perceptible surface change from the control sample; ?? = one but not both samples show deviation from the control sample (or inconclusive results); and No = no perceptible change observed between exposed and control samples.

microscopy after exposure at 30, 60, and 100 day intervals. No visual changes were observed at 50x, 100x, or 250x magnification using both bright field and dark field illumination. In addition the color of each sample was measured in CIE-LAB units and ΔE was calculated between pre- and post -exposure measurements. No changes in surface appearance were found on any glass sample after 100 days of exposure to 1200 ppb of formaldehyde gas.

Shells

Optical microscopy was used to investigate all shell samples after exposure. Although the irregular surfaces of the shells made comparison of control and exposure samples difficult, no surface changes after the 30 day interval were observed. After 100 days, the exposed and control samples of nautilus and abalone shells did show what may be efflorescence and were investigated further with ESEM analysis. Because the abnormalities on the surfaces could not be positively identified as efflorescence, and were seen on both the exposed and control samples, the results were considered inconclusive.

Ceramic Glazes

The appearance of the glazed ceramic tiles was investigated with optical microscopy at 50x, 100x, and 250x magnification. Color measurements were performed in the same manner as for glass samples. No changes in surface appearance were found on any ceramic glazed sample after 100 days of exposure to 1200 ppb of formaldehyde gas.

Metals

Changes in the appearance of the metal alloys were investigated using optical microscopy (at 50x, 100x, and 250x magnification) and Environmental scanning electron microscopy (at 1400x, 4200x, and 10,000x magnification). Of the materials tested, metal alloys showed the most sensitivity to formaldehyde exposure as seen in Table 3D. Four of the nine alloys investigated displayed conclusive visual changes after exposure to 1200 ppb formaldehyde in 30 days. These included brass, bronze, lead, and zinc. An additional three alloys, silver, tin, and iron, gave inconclusive results. By the end of the 100 day exposure, seven of the nine alloys showed definite changes from the control samples.

Based on visual results, copper and copper based alloys (brass and bronze) initially developed thin tarnish or corrosion films after formaldehyde exposure. Both copper and brass displayed corrosion films consisting of sub-micron particles that tended to congregate along scratches or deformations in the surface. But the rate of corrosion differed for these two metals. For the

brass samples, initial corrosion films were seen after 30 days of formaldehyde exposure. The copper samples developed tarnish films after 60 days of exposure. The corrosion film found on the bronze samples after 30 days tended to be made up of individual particles randomly located on the surface. After 100 days exposure the corrosion film on all copper based samples tended to approach micron thickness in some areas. In addition, small corrosion blooms were found in pitted areas on the bronze samples. Visually, it appeared that two types of corrosion processes were active on the bronze samples. The nature of the films were not evident by particle shape. And the small size of the corrosion particles did not allow for characterization using X-ray diffraction techniques.

There was a possibility that paraformaldehyde used in the permeation device to generate the formaldehyde atmosphere may have precipitated out onto the sample surfaces. A simple test was performed to determine if the film was paraformaldehyde. A site on the surface of a 100 day exposure bronze sample was selected near a corrosion bloom, and a cross hatch was engraved as a reference marker. An electron micrograph of the surface was taken to document the site. Then, the sample was placed in an oven at 100 °C for 72 hours (at this temperature paraformaldehyde sublimates to formaldehyde gas). Re-examination of the sample site showed no change in the surface film, thus ruling out paraformaldehyde precipitation.

The bronze 100 day exposure sample was investigated further using energy-dispersive spectroscopy surface analysis. Analyses were performed at five locations as noted in Figure 2. Locations included areas with little corrosion and pitted areas which displayed corrosion blooms. The results of these analyses (given in Table 4) showed that the bronze alloy was heterogeneous. Lead tended to pool out of the alloy at pitted areas, resulting in low concentrations of lead at other locations on the surface. The formation of corrosion blooms in surface pits may indicate preferential attack by formaldehyde on lead within the alloy. Individual corrosion particles, similar in shape and size to those found on copper and brass samples, were seen at other locations on the sample where the concentration of copper was much higher. These facts support the premise that two corrosion processes may be taking place on the bronze alloys.

Silver and sterling silver displayed evidence of corrosion at a slower rate than the copper based alloys. Conclusive evidence of corrosion was found on sterling silver after 60 days and on pure silver after 100 days of exposure. Sub-micron corrosion particles were seen on both materials. However, on the sterling silver these particles tended to form islands approximately 5 microns in size. The islands were grouped near deformation sites. A discontinuous corrosion film was formed by individual particles on the pure silver samples.

TABLE 4. EDS ANALYSIS OF EXPOSED BRONZE SAMPLE SHOWING HETEROGENEITY.

LOCATION	% COPPER	% TIN	% ZINC	% LEAD
1	6.4	1.1	0.6	92.1
2	7.4	0.4	0.7	91.8
3	90.7	5.1	3.2	0.5
4	92.3	2.6	3.4	1.7
5	92.9	3.1	3.6	0.4

EDS analysis performed on Electroscan Environmental Scanning Electron Microscope using a Link Analytical System. Instrumental conditions: 20 kV, 150 μ A beam current, beam size 30, 25 ° sample tilt.

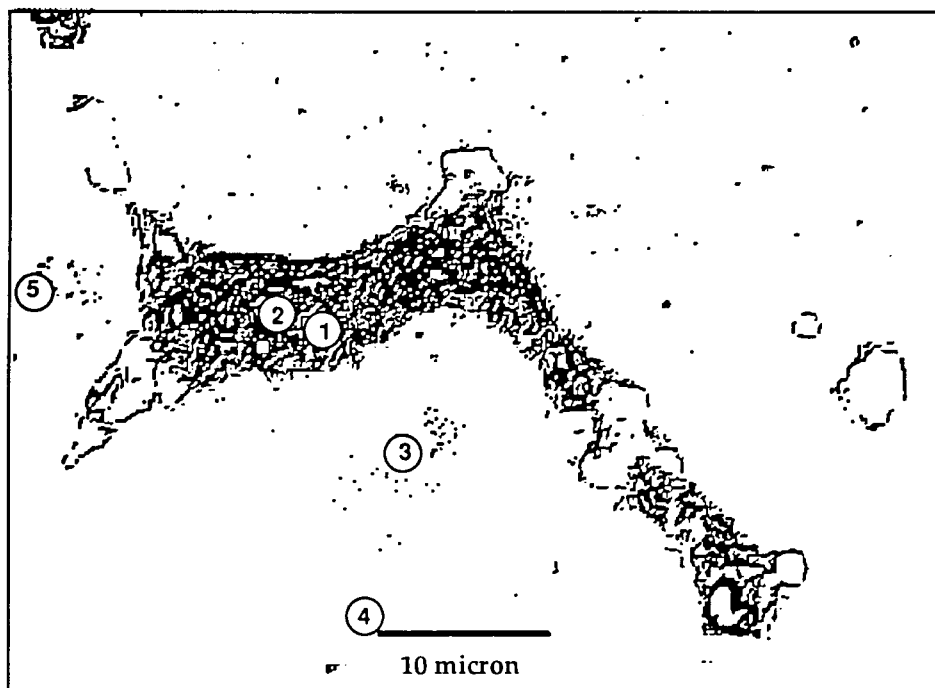


FIGURE 2. Illustration showing the locations of EDS analysis on exposed bronze sample (see TABLE 4). Each location is marked by a circle containing the location number. 1450 x magnification. The black areas designate corrosion on the surface of the bronze. Corrosion took place preferentially in pitted areas and areas of high lead concentration.

Zinc corrosion films were also seen upon exposure to formaldehyde. The corrosion was first observed after 30 days of exposure. The film was made up of sub-micron banana or propeller shaped crystals, similar in morphology to zinc oxide. This type of film was not seen on the control samples, which may indicate an acceleration of zinc oxide formation in the presence of formaldehyde. However, the identification of zinc carbonates or formates as the corrosion product cannot be ruled out.

The results of formaldehyde exposure on tin and iron were inconclusive. Although signs of corrosion were seen on exposed samples for each material, similar corrosion was also found on the control samples. The possible role of formaldehyde in the corrosion processes could not be determined.

Corrosion products were also found on surfaces of exposed and control samples of lead after all exposure time intervals. The corrosion films were readily seen in dark field illumination by optical microscopy and by electron microscopy. The crystalline particles of the corrosion films on the exposed and control samples differed significantly. Tetragonal particles with occasional needles were found on the control samples, while columnar groupings were observed on the exposed samples. A standard lead sample containing basic lead carbonate crystals was compared to the exposed samples. Based on the morphology of the corrosion products the exposed corrosion film was tentatively identified as basic lead carbonate. The tetragonal particles found on the control samples may be lead oxide which readily forms on lead surfaces. It was not possible to identify the corrosion products by X-ray diffraction analysis.

CONCLUSIONS

This survey investigation shows that, of the four types of inorganic materials studied, metals and metal alloys are most sensitive to 1200 ppb formaldehyde gas. Of the nine metals and alloys examined, seven showed apparent damage after 100 days of exposure to 1200 ppb of formaldehyde. Based on visual observations after 100 days exposure, the sensitivity of metals to formaldehyde (in decreasing order) is lead > bronze > brass > zinc > copper > sterling silver > silver. Inconclusive results were obtained on examination of tin and iron.

Other inorganic materials studied were much less susceptible to damage by exposure to formaldehyde. Although shells may be sensitive to formaldehyde exposure, the findings of this study do not conclusively indicate active formation of efflorescence at 1200 ppb of formaldehyde over a 100 day time interval. The commercially available stained glasses and

ceramic glazes exhibited no visual changes after exposure to formaldehyde under these conditions.

The results presented in this paper represent preliminary findings. The chemical composition of corrosion products was not determined due to the nature of the thin corrosion films found. Future research may focus of chemical identification and quantification of these corrosion products, as a first step in elucidating the reaction mechanisms and materials damage functions upon exposure to concentrations of formaldehyde similar to that found in the museum environment.

ACKNOWLEDGEMENTS

I would like to acknowledge the team of scientists at The Getty Conservation Institute which were instrumental in the implementation of this project. Thanks go to Dusan Stulik for valuable discussions and guidance in the planning and supervision of this project. David Scott provided insights into the metallurgical investigation, as well as X-ray Fluorescence support. Michele Derrick and Jim Landry provided technical support for attempts at corrosion product identification. Discussions on experimental design and HPLC analyses were provided by Cecily Grzywacz.

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Fixtures at an Exhibition:
Results of Practical Tests for a New Museum
Part I

Donna K. Strahan*

Last month the Walters Art Gallery opened Hackerman House a newly renovated 1850's mansion devoted to the display of Asian Art. The building is located on historic Mt. Vernon Square in Baltimore, Maryland. It is connected to the Walters by a bridge and now houses over 900 objects on two floors. The first floor is set up as a 19th c. Asian art connoisseur's residence, necessitating the reuse of existing built-in library cases and period cabinets and furniture. The second floor is set up as a modern exhibition space where many new exhibition cases in a range of shapes and sizes were needed to house the wide variety of objects in the collection.

The Exhibits Department at the Walters works very closely with the Conservation Division and many discussions and tests were carried out before case construction for Hackerman House began. The testing of materials to be used in the museum environment has been performed by the conservation laboratory since the early 1980's. It is museum policy that before the exhibits department uses any fabrics, glues, woods, sealants, paints, etc. samples are sent to the lab for testing. Since we have been testing on a regular basis, no damage has occurred from improper case or storage materials. In this paper I will only speak about the wood products and sealants we tested for Hackerman House.

Let's remind ourselves why testing is so important by looking at a few of the past problems which occurred at the Walters because of the use of untested materials in exhibition cases and storage areas.

Back in 1979, the yellow fabric used to display an Islamic sword caused severe irreversible damage to the blade. It is not clear exactly what was in the fabric to cause the damage but if it had been tested first it certainly would have failed and thus not been used.

While it is very difficult to grow silver sulfide acanthite crystals in a laboratory, we have been able to grow them in our storeroom. In the second example, rubber mats used in storage released sulfur as they began to deteriorate. They caused irreversible damage to hundreds of metal objects. These are just two examples of previous problems due to poor selection of materials to be used near art objects.

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The Walters is a small public museum without the scientific instrumentation and staff to analyze the selected materials. Therefore, our testing methods are simply a modification of the empirical test Oddy described in the 1975 Stockholm preprints in an attempt to correlate our results with actual museum situations. Often several different samples for each situation are tested. Therefore, if the first selection fails a second choice can be made from the samples which passed. The exhibits department is always racing for an opening deadline and needs quick answers.

Tests involve a jar, with a sheet of mylar on the bottom to separate the test materials from condensation; a test tube with distilled water; the sample with polished and degreased metal coupons - Cu, Ag, Pb, Fe. Since the tests are run for both vapor corrosion and contact corrosion the coupons are partially set in contact with the material being tested. All tests for permanent exhibitions are run with a control jar for 1 month at 40°C. Tests for temporary exhibitions are run for two weeks. The control is run with metal coupons to determine if any change occurred due only to heat and humidity. Using the control coupons for comparison, each jar's coupons are visually inspected for signs of corrosion.

The exhibits department wanted to use one of two wood products for building the cases for Hackerman House. Because solid wood was too expensive they selected MDO plywood and MEDEX. MDO or Medium Density overlaid plywood is made of softwood veneers and phenol formaldehyde adhesives and resins. In the past this was the best material available to us even though it is horrible. Then Medex came along with better working properties. Medex is a trade name for a particle board made of chipped softwoods and combined with a polyurea resin matrix. The company says that it contains no formaldehyde. Just knowing the ingredients was enough to turn them both down. But we had no other alternatives.

Ann Boulton (see Part II) and I initially tested a single sample of both wood products. Since whichever product was selected, it had to be sealed, we also tested the wood products with three sealants. However, the results were confusing. Therefore, about 10 samples of each, (10 plain MDO, 10 plain MEDEX, 5 of each sealant on glass slides, 10 MDO coated with each sealant - 30 samples, 10 MEDEX coated with each sealant - 30 samples) a total of 95 samples were tested in order to gain a more consistent result.

Several peripheral but important points were learned from these tests:

1. A tight seal on the test container is necessary. We found that the loss of water negated the test. Jars where

water evaporated gave no reaction. All jars with water still present had a reaction occur - if the material was corrosive. Therefore, it is easy to misinterpret a single test if all factors are not considered.

2. Use of cotton in the test tube as is usually recommended did not alter the RH within the jar. We performed tests with cotton in the test tubes at the bottom, top and test tubes with no cotton. They all read 100% RH within an hour. Note: the paper RH strip has corroded the copper coupon.

The results that you see are typical of each product. All coupons of the MDO samples were extremely corroded, particularly the Pb and Fe. This is probably due to the formaldehyde resin. All samples of MEDEX had very slight corrosion on the Pb and none on the other coupons. (Fig. 1)

A rough idea of the pH of the two wood products was determined by placing pH strips in jars with the samples. Controls were run with water and without water. The pH of both Medex and MDO is 4 to 5. Since both products are made of softwoods it is not surprising that they have a low pH.

Of these two wood products Medex was the superior one, although it was not perfect. It is very expensive compared to MDO but the carpenters prefer it because it can be milled like wood. Therefore, Medex was selected for use in the new museum but the search for a replacement is ongoing.

Because the selected wood for building the cases was not perfect it was hoped that a sealant could be found to seal all the interior surfaces of the case and prevent off-gassing. We all know that the ideal case would be made of aluminum and glass or at least sealed with Marvelseal (a laminated material which does not allow vapor transmission made of aluminum foil, nylon, polyethylene) or saran wrap but these suggestions met with opposition from exhibits. So a compromise was made.

Three sealants were chosen for testing. All are water-borne coatings and therefore not offensive or hazardous for the shop to work with.

1. Polyglaze by Camgar - water-borne polyurethane
2. Fabulon by Fabulon Products - water-borne polyurethane
3. Shieldz Primer by Wm. Zinsser and Co. - water-based acrylic paint

First, each was painted on an inert glass slide, air dried and tested by itself without wood. All three passed; therefore, any corrosion which occurred in further tests on wood samples would probably be due to the wood products and not the coating.

Next, two coats of each sealant were painted on cubes of MEDEX and MDO in order to see if the sealant would actually act as a barrier and prevent the wood from corroding the coupons. Again 10 samples of each coated cube were tested. The results show that none of the coatings is an adequate sealant, but Shieldz Primer is the best of the three. (Fig. 2)

The cases in Hackerman House are intentionally not air tight to avoid a build up of any gases. Pb coupons are placed in an inconspicuous location in the case to monitor any organic acid pollutants.

In summary, this simple empirical test method is valid, inexpensive and requires little time. It appears from our testing that Medex, with a polyurea resin matrix along with its good working qualities, is the most reasonable product for cases at the moment. Of the sealants, the acrylic water based paint sealed best. The problem of off-gasing while not eliminated is cut down with the sealant. However, these materials are proprietary materials and the formulas change without notice, so it is important to test and retest frequently.

Since we do not work in a vacuum but work with other museum people who have different needs and monetary limitations, situations will not always be ideal. There is no perfect material. But we are doing our best to control the exhibit environment within the capabilities of the institution for which we work.

Normally we do not have time to run more than one sample of each material, but at present we have Matthew Crawford, a volunteer in the lab, who is very dedicated to the project. Therefore, we are able to do more thorough testing of materials.

Don't forget to test your case materials. You never know what might come out of them. Thank you.

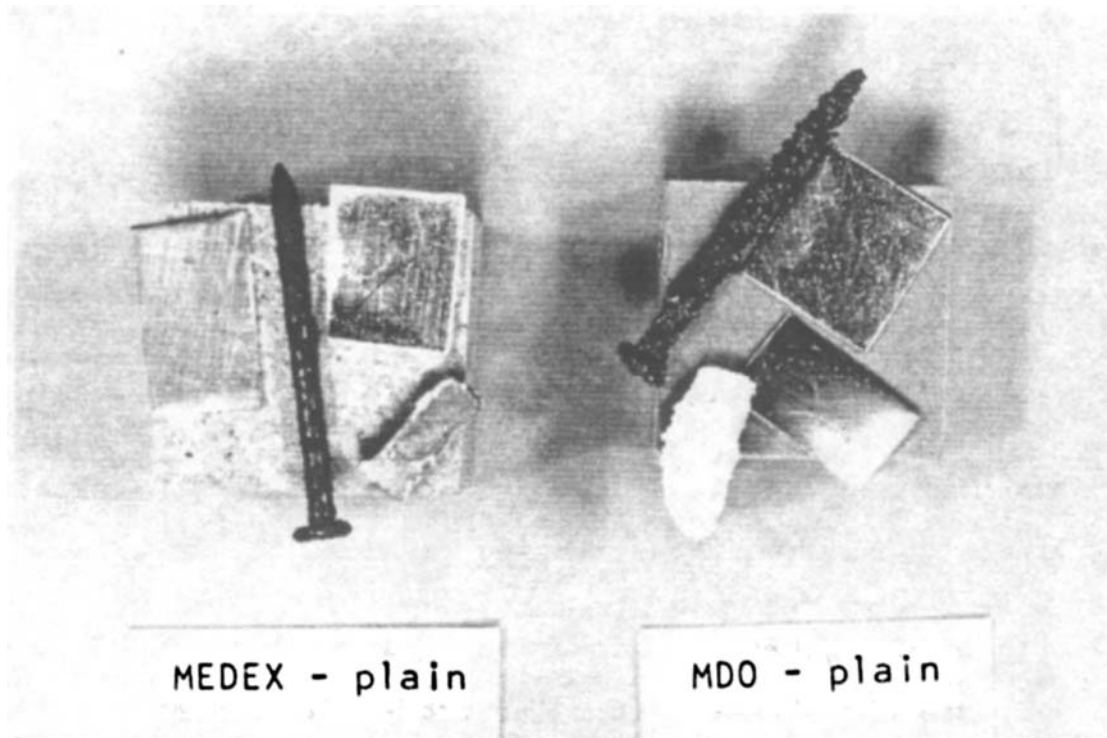


Fig.1. Examples of metal coupons on blocks of uncoated MEDEX and MDO after testing.

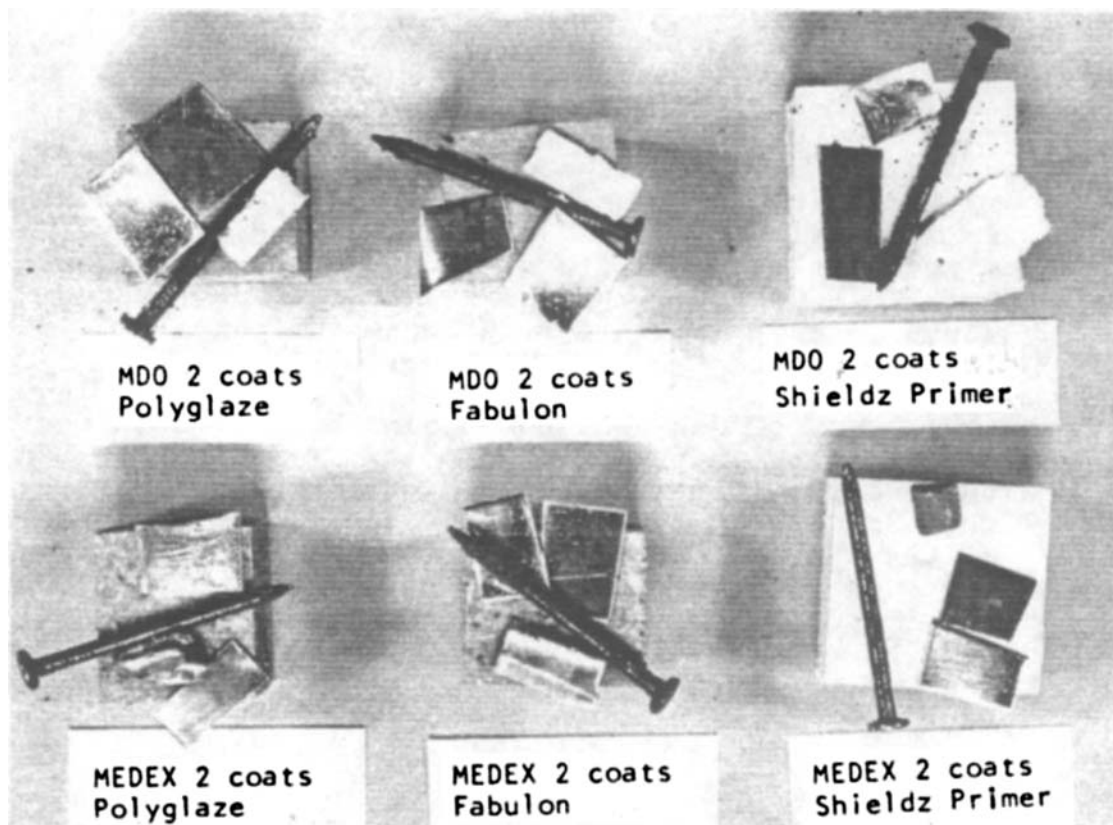


Fig. 2. Examples of metal coupons on blocks of MEDEX and MDO coated with various sealants after testing.

FIXTURES AT AN EXHIBITION: RESULTS OF PRACTICAL EXPERIMENTS
FOR A NEW MUSEUM--PART II. Ann Boulton*

INTRODUCTION

For those of you who missed Donna's talk this morning a brief introduction to Hackerman House. Hackerman House is a mansion built in 1850 which was recently acquired by the Walters Art Gallery in Baltimore. The house has been physically linked to the Walters Art gallery by an elevated walkway across the alley which separates the two buildings. Hackerman House has just undergone extensive renovations and now functions as the Walters Museum of Asian Art. The galleries opened to the public on May 5th of this year. My talk will discuss one small aspect of the design for the exhibit cases which were built to house the Asian collection.

Ten of the cases for Hackerman House were intended to hold archaeological objects made of bronze. A number of these objects had a past history of bronze disease, and we wanted to create a microclimate with dry silica gel of 30% RH in these cases to prevent further outbreaks of bronze disease.

Microclimates such as these had certainly been established in the past at the Walters, but we had had some problems in achieving low relative humidity which we believed were due at least in part to the deck design of the cases. One design was to leave a quarter inch gap around the edge of the deck to allow for the passage of air from the silica gel compartment to the case vitrine where the art object was displayed (figs.1 & 2). We felt that the quarter inch gap was not wide enough and wanted to widen this gap to a half inch. This was very unpopular with the exhibit designer. He never liked the quarter inch gap and hated the idea of a half inch gap.

Another type of deck which had also been used in the past at the Walters but not without problems was a perforated deck with no gap left at the edges. Once the deck was covered with fabric the holes were not visible. We were concerned that the type of fabric chosen to cover the holes might affect the passage of air between the silica gel compartment below the deck and the object compartment above. This deck design was the favorite of the exhibit designer because there was no unsightly gap around the edge as with the other design.

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EXPERIMENT

Donna Strahan's and my experiment was in two parts. The first part was to compare the efficiency of the three types of wooden unsealed decks: the solid deck with a quarter inch gap at the edge, the solid deck with a half inch gap at the edge and the perforated deck with no gap at the edge. This was done by measuring the time it took the air in each test case to become dry. Our reasoning was that if the deck design inhibited the flow of air then it should take longer for the air in the case to become dry.

The second part of the experiment was to compare some different types of fabrics used to cover the perforated decks. We wanted to know if the fiber content or weave would affect the flow of air from the silica gel compartment. Again this was done by measuring the time it took the air in each case to become dry. Fabrics chosen for comparison were: wool, 100% cotton, and 50/50 cotton-polyester blend. Wool was chosen for comparison because it was a thick, tightly woven fabric. We do not use wool in our exhibition cases.

The design of the first part of the experiment was as follows: four test cases were constructed of MDO plywood (this was before we switched to Medex) and four Plexiglas vitrines were ordered. These cases were of the "table top" style that was used extensively in Hackerman House. The plywood was allowed to sit for several weeks in the 50% RH environment of the museum before the cases were constructed. The vitrines were 8 cubic feet in volume so 4 pounds of silica gel were placed in the bottom of each case. (We use a formula of 8oz. of silica gel per cubic foot of airspace). The silica gel had been dried for several days in our oven and was near 0% RH. Over the dry gel the plywood decks were installed, one with a quarter inch gap, one with a half inch gap and one with perforations only. The MDO plywood used for the decks had a factory-applied primer on both sides, but we did not seal the edges as we were still testing sealants at this stage. The fourth case had no deck and was used as a control. Pastorelli and Rapkin hygrometers calibrated to a recording hygrothermograph were hung from the top of each vitrine and the cases were closed.

The relative humidity in the cases when they were closed was 50%. The drop in relative humidity was recorded at irregular intervals (fig.3). From this experiment we saw that there was very little difference in performance between the decks with the quarter and half inch gaps and that the perforated deck appears to be slightly more efficient. Now a disclaimer. These hygrometers are not terribly accurate so slight differences of 2% or so must be discounted.

We all know that wood itself is a good buffer. It is true

that the perforated deck had 5.5 ounces less wood in it. This amount of wood was removed during the drilling of the holes in the deck.

No doubt the smaller amount of wood in the deck released less moisture in the air which could account for the greater efficiency of the perforated deck. Was the perforated deck more efficient only because it contained less buffer material or did the actual design of the deck influence it also?

To shed some light on this question we did two more experiments. A solid wooden deck with a quarter inch gap was compared with a solid Plexiglas deck with a quarter inch gap (fig.4). Next, a perforated wooden deck was compared with a perforated Plexiglas deck (fig.5). Our thought was that the Plexiglas would release very little moisture and should be more efficient than the wood decks if the design had no influence. The results of the tests show that the solid decks are nearly identical in efficiency no matter what their material. The perforated plexiglas deck is more efficient than the perforated wooden deck. From this pair of experiments we can deduce then, that the smaller amount of buffer material does have an effect but that the design of the deck is also a factor. You might wonder whether the perforated deck simply has more surface area exposed for the air to travel through. That is actually not true. The deck with the half inch gap had slightly less than 20 square inches of unobstructed surface area around it and the perforated deck had slightly less than 16 square inches of unobstructed surface area. We selected the perforated decks for our cases as they performed slightly better for whatever reasons and because they were preferred by the exhibit designer.

The second part of our experiment was to test several different fabrics to see whether fiber content or weave would affect the ability of air to pass through the deck. We chose 100% wool, 100%cotton and 50/50 cotton polyester blend. The experiment was set up in the same manner as the first one except that all the decks were perforated, each covered with a different fabric and the control was a perforated deck with no fabric. You can see from the chart (fig. 6) that there is very little difference in the response of the control with no fabric to that of the wool and the cotton poly blend. The cotton appears to slow down the RH drop slightly. Of course a fabric like Ultrasuede which has a plastic backing would affect the ability of the air to pass through the deck. This may seem quite obvious to us but it might not be obvious to the exhibit designer.

How did these decks work in real life? Of course there are many problems. The concept of controlling the environment with silica gel for some reason seems to elude other museum

staff members. The first problem was that the deck fabric chosen was thin and white through which you could see the holes in the deck. So another layer of heavier fabric had to be put on the deck first. Then the decision was made to staple silver cloth to the underneath side of many decks so that the dry air ultimately had to penetrate three layers of fabric in some cases. Then much of the exposed deck was covered with labels. This was alleviated by putting small matboard spacers under each label to lift it slightly off the deck. When objects were displayed on large fabric covered blocks we requested that holes be drilled in the backs of the blocks. In some cases objects were displayed on already existing bases made of solid stone rather than on fabric blocks. We are lobbying to have spacers put under these bases to lift them slightly.

To see what effect three layers of fabric would have on the air flow we did yet another experiment in which we compared a perforated deck with no fabric to one which was covered with three layers: 100% cotton velveteen, 100% cotton sateen and 100% cotton flannel (silver cloth). Two of these three layers were rather thick and all were made of cotton which is also a buffer. We were rather surprised to see that there was very little difference in performance of the two decks (fig.7). The fabric layers did not seem to inhibit the air flow.

SUMMARY

Our experiments helped us choose the most efficient deck design for our new cases. The perforated deck seemed to be more efficient than the solid decks with gaps at the edges. This was not only because there was less wood to act as a buffer in the perforated deck but was also partly due to the actual design of the deck. The fabric covering the holes of the perforated deck did not seem to inhibit the flow of air as one might expect. Neither the fiber type nor the number of layers of fabric had any real effect on the air flow.

The problem with perforated decks in actual use is that because the holes are covered with fabric, non-conservation museum staff forget about them. Many things can be put on the decks such as labels and blocks which cover the holes and prevent the passage of air. The exhibition staff has to be frequently reminded that the holes must remain unblocked to allow the silica gel to do its job.

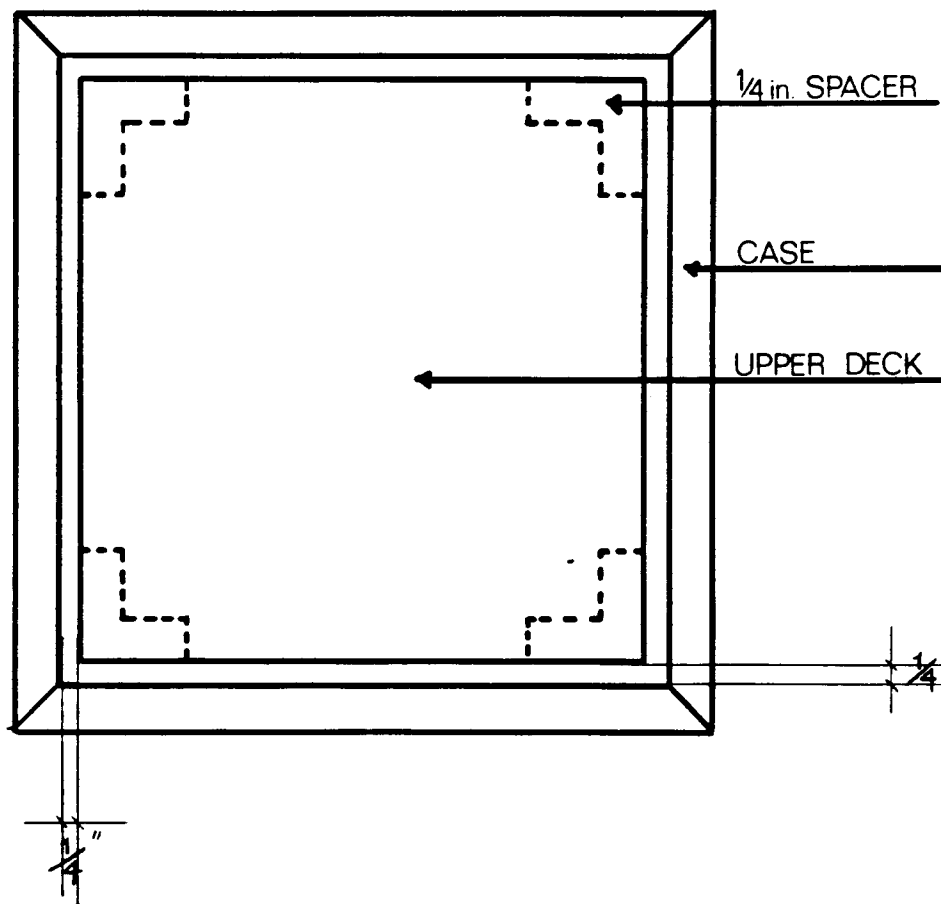


fig.1 Top view of deck with
quarter inch gap.

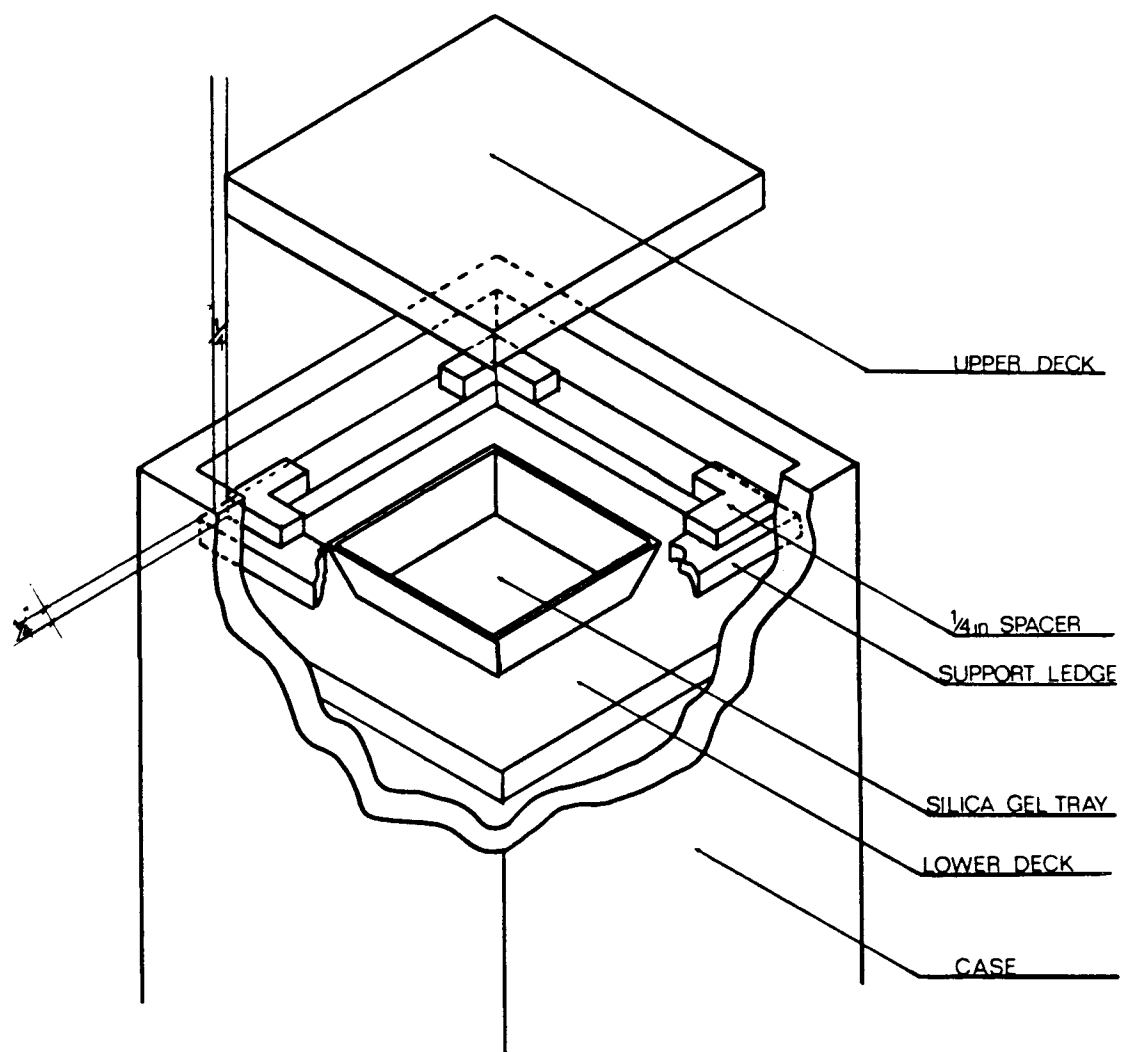


fig.2 Case with deck with quarter inch gap.

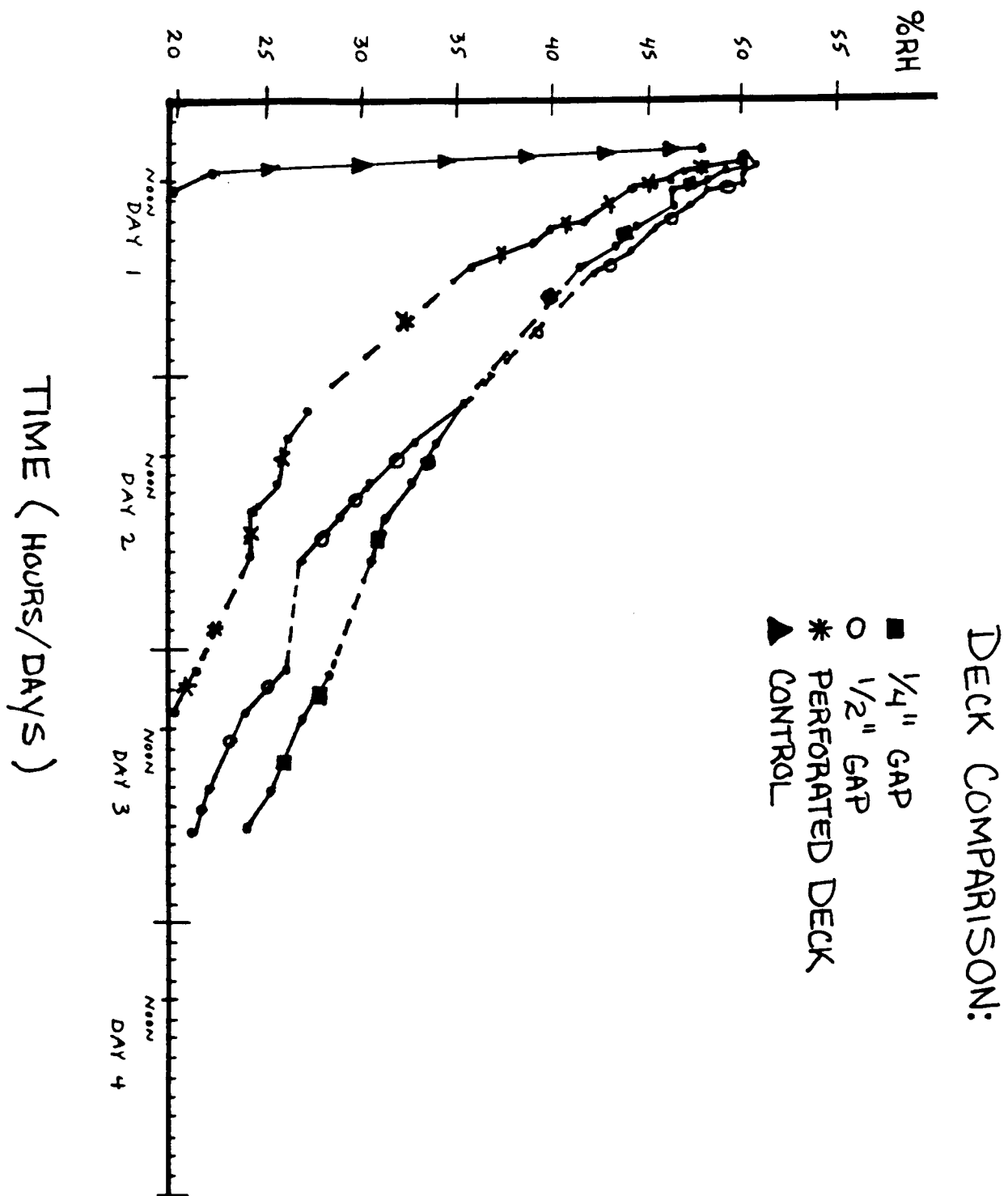


fig.3 Deck comparison

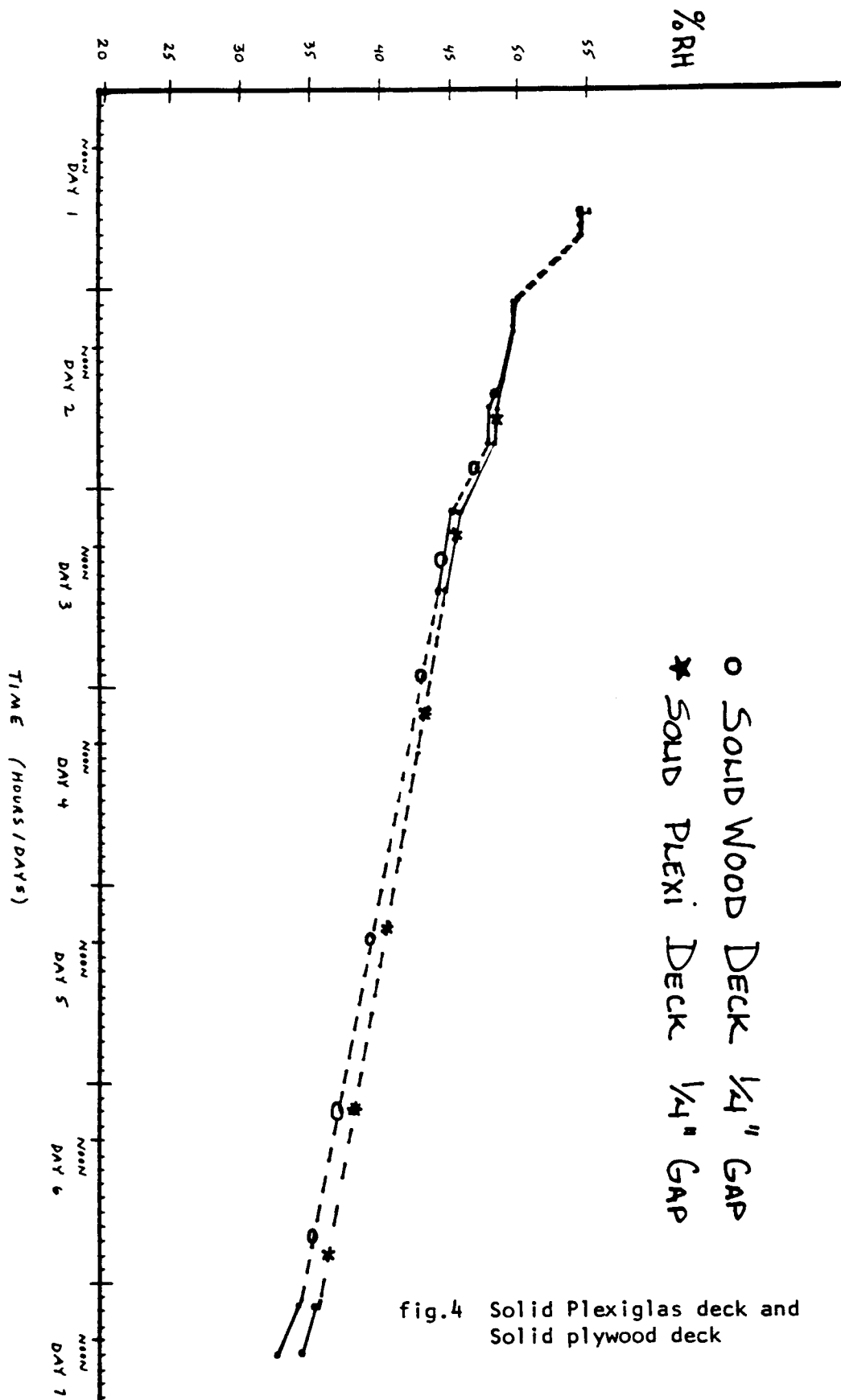
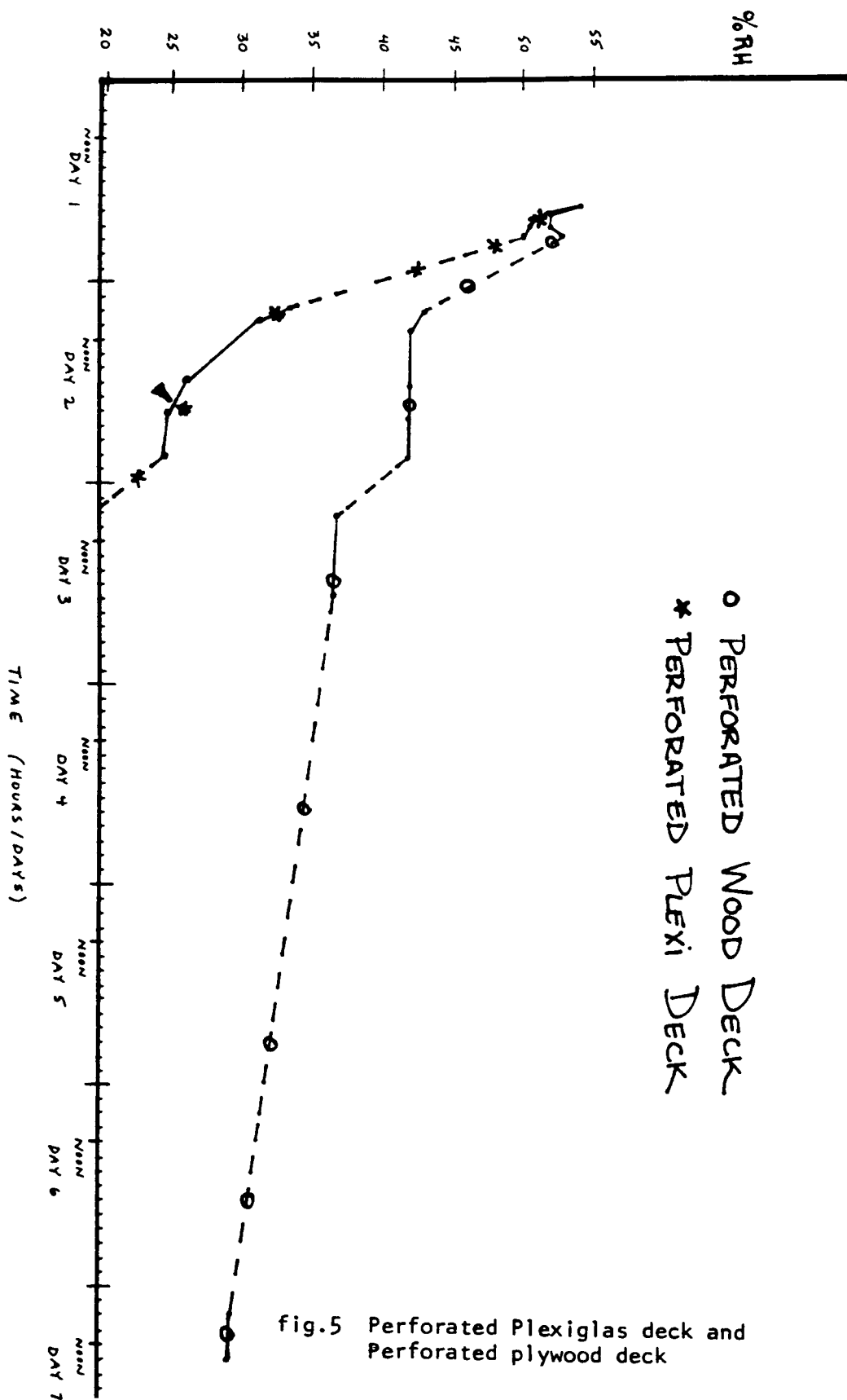


fig.4 Solid Plexiglas deck and Solid plywood deck



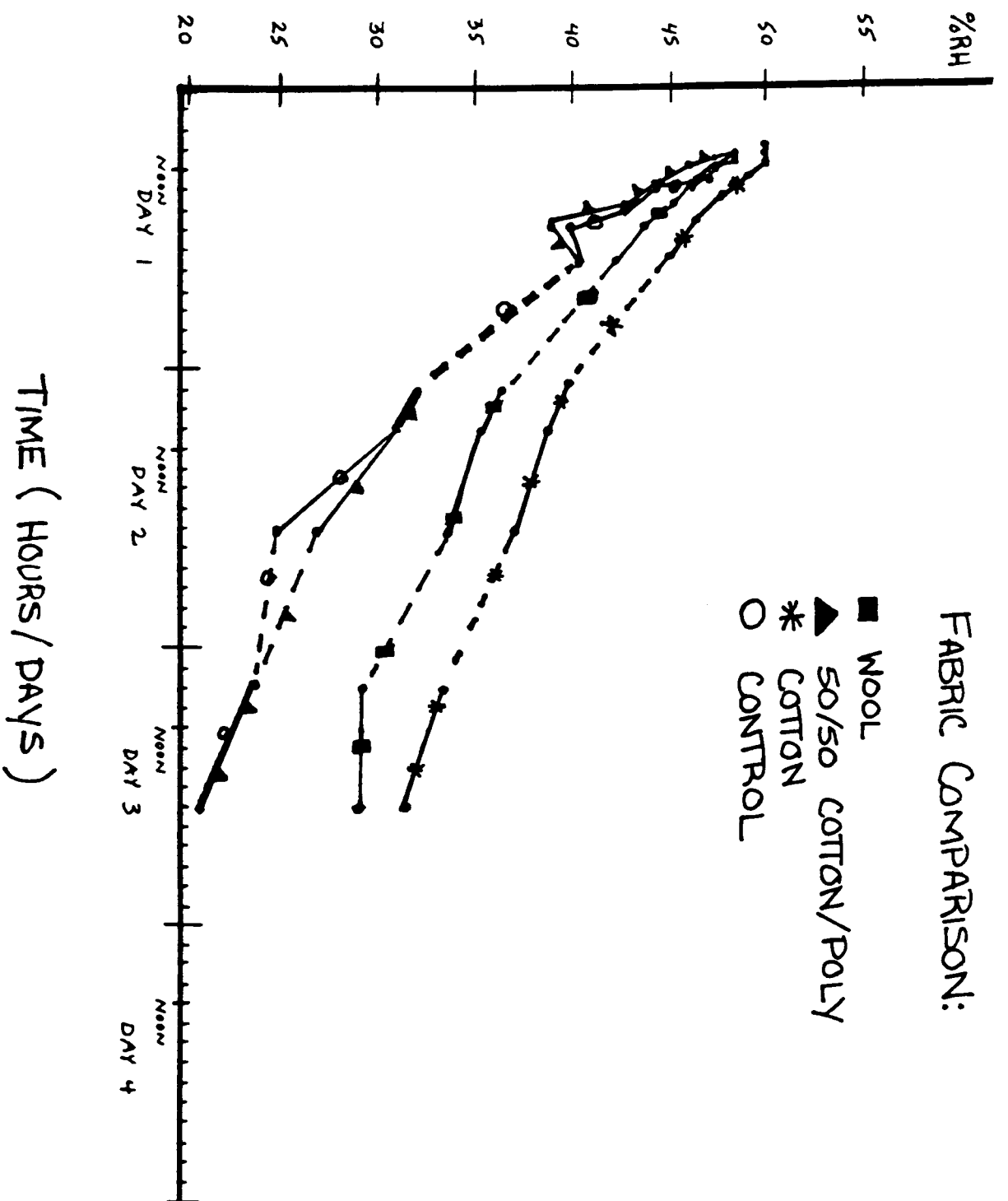


fig.6 Fabric comparison

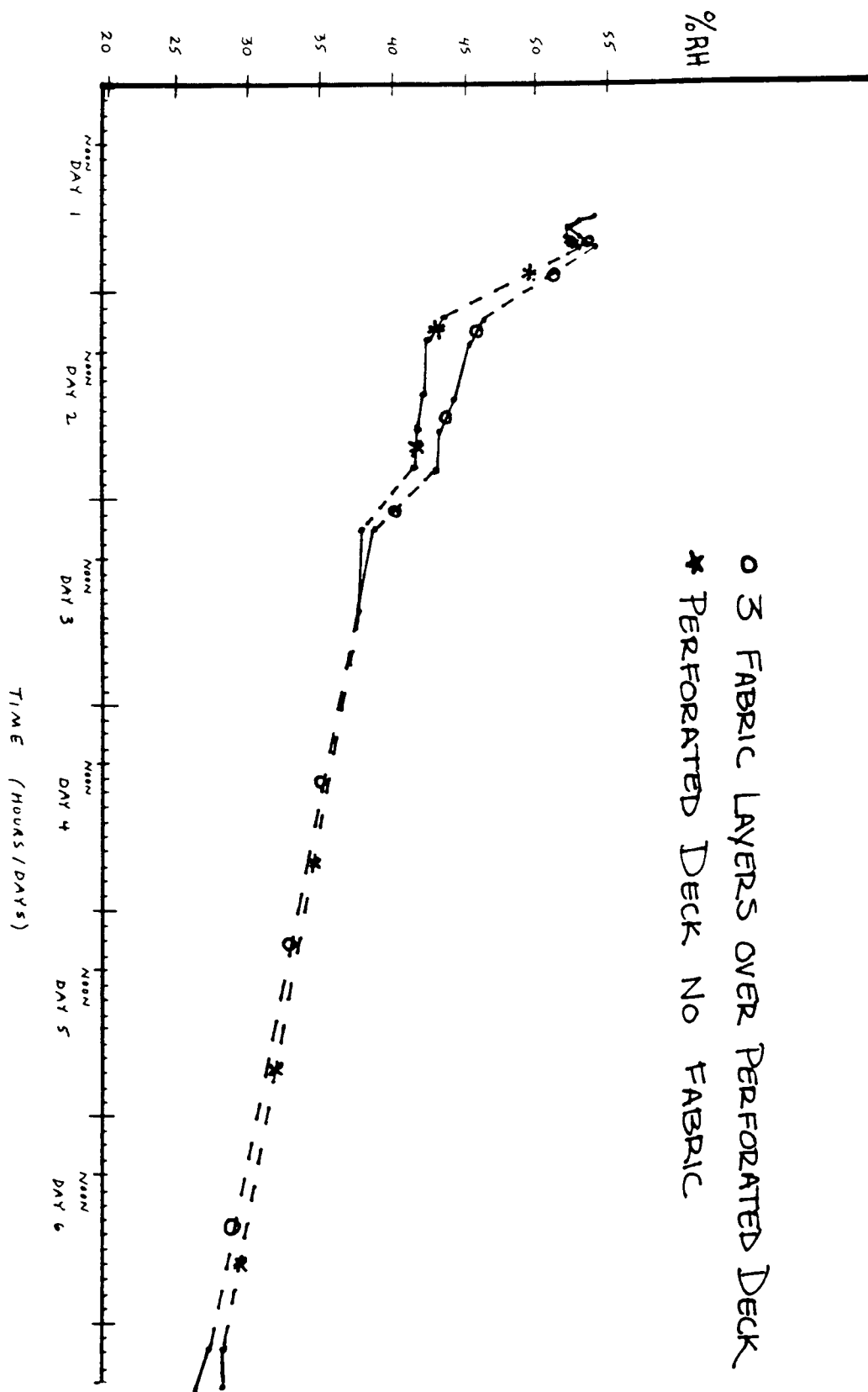


fig.7 Three layers of fabric

ANALYSIS OF VOLATILE ORGANIC COMPOUNDS FROM DISPLAY AND STORAGE CASE MATERIALS

James M. Landry, Senior Fellow, Michael R. Schilling, Associate Scientist, and Dusan C. Stulik, Head, Analytical Section, The Getty Conservation Institute, 4503 Glencoe Avenue, Marina del Rey, CA 90292.

Extended Abstract: It is well documented in the conservation literature that volatile organic compounds (VOC's) emitted from building materials may damage works of art. Sulfides, organic acids and aldehydes are only a few of the many chemical compounds that are known to attack objects. In general, VOC's pose a greater risk inside display and storage cases, where the rate of air exchange is kept intentionally low.

Therefore, much effort has been made to develop methods for testing display and storage materials prior to their use. Methods that have gained wide acceptance include the Oddy test, pH test, and the azide microchemical test for reactive sulfur compounds. The results from these tests provide a means for determining whether or not the material in question may harm objects.

A program of research is currently underway at The Getty Conservation Institute (GCI) which focuses on detection and identification of VOC's emitted by commonly used display and storage materials.

In the first part of the project, a materials survey was distributed to approximately 1600 display professionals and objects conservators. The intent of the survey was threefold: 1) To identify the most commonly used products in display, storage, cleaning and transportation of objects; 2) To discover other test methods; 3) To identify materials that have been suspected of causing harm to objects. The results of the survey will be sent to the National Association for Museum Exhibition (NAME) for publication in their newsletter, The Exhibitionist.

The second phase of the research deals with development of a method for detection and identification of VOC's using thermal desorption-gas chromatography-mass spectrometry (TD-GC-MS). Briefly, TD-GC-MS involves: 1) Pre-concentration of VOC's emitted from a sample by adsorption onto sorbent traps, in this case highly purified carbon; 2) Transfer of adsorbed VOC's from sorbent trap to the GC by thermal desorption; 3) Separation of the VOC mixture by gas chromatography; 4) Detection and identification of individual VOC's by mass spectrometry.

TD-GC-MS has many advantages over other methods. It is

especially useful for analysis of VOC's because it provides positive identification of the compounds emitted by materials. In addition, the technique possesses the very high sensitivity required to detect the low VOC concentrations typically produced by materials. The method can also be used in the collection and analysis of ambient air samples. This feature permits the study of pre-existing display and storage cases, and gallery conditions. Finally, the method can be used to determine the concentration of VOC's, which allows the kinetics of volatile off-gassing to be studied.

USE OF AN ENVIRONMENT TEST KIT IN MINNESOTA

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The concept for a portable test kit was one that originated at the Canadian Conservation Institute and was adapted by Barbara Moore, then with the Arizona State Museum, and this author then with the Arizona Historical Society. As one component of a two year preservation outreach project, the Minnesota Historical Society assembled two test kits for loan to institutions throughout Minnesota.

The kit consists of three instruments and four other testing or monitoring components, packed in urethane foam within a hard shell suitcase that has a combination lock. The kit includes a INS (model LX-101) digital light meter reading in units of lux (from Edmund Scientific), and Elsec model 762 UV light meter, a Psychro-Dyne battery operated psychrometer (from Cole-Parmer), a copy of The Museum Environment (2nd edition), an Abbey pH pen, a humidity indicator card (from Humidial), a blue wool card (from Talas), spare batteries and an instruction manual. The manual describes the purpose and gives instructions on the use of each item in the kit. It also includes a sample form for recording temperature, humidity and light levels, a list of suppliers with addresses and phone numbers, and the phone number for MHS' object conservator should there be any questions or problems. Each borrower keeps the following items: instruction manual, pH pen, blue wool card and humidity indicator card.

The kit is shipped insured via U.S. mail or UPS to be used by each borrower for a period of one week. At the end of the loan, the kit is either returned to MHS or sent on to the next borrowing institution. Scheduling and coordination were originally handled by Preservation Outreach Project staff, and are now accomplished by MSHS' Field Services Coordinator with occasional assistance from the Conservation Department. Aside from staff time, the only expense to the borrower is the cost of return shipping and insurance.

The target audience for the kit includes small and medium size museums, special and academic libraries, and academic, city, county and court archives. It was found that larger institutions were also quite eager to avail themselves of the service. In many cases their more sophisticated staff despite their understanding of the problems, did not have access to the proper equipment.

The objectives were several: 1. Provide instruments for small institutions that might not have the resources to purchase them; 2. Enable staff to gather and use meaningful data rather than having to rely on a consultant; 3. Eliminate the fear and

aversion that minimally trained staff often feel about science or "high tech" conservation by selecting easily used instruments and providing uncomplicated, easy to follow instructions; 4. Emphasize that simple, practical, and manageable monitoring is the first step in controlling and improving environment; 5. Finally, that environmental control is a preventive conservation measure which yields significant benefits to the entire collection, not just a few items or even a specific group that is but a small part of the whole.

The program has been popular and successful. The kits are usually reserved and scheduled several months in advance. They are being used both by new users and by institutions who have previously used the kit and wish to monitor spaces during different seasons. In addition to raising awareness of conditions and educating staff, the kit has led to substantive improvements and changes and several institutions. One museum used the data gathering in a successful grant proposal to install a new exhibit lighting system. Several other institutions have installed temporary humidity control, while one secured a grant to upgrade an HVAC system.

The need for more extensive data on temperature and humidity is now being addressed with the addition of several ACR temperature/humidity dataloggers (model XT-102, from Herzog/Wheeler, Minneapolis). These self-contained units suffer no damage from frequent movement and shipping and do not require the frequent calibration as do recording hygrothermographs. The datalogger is accompanied by a form (for logging time and date installed and removed) and an instruction manual. The manual describes the importance of temperature and humidity control and makes suggestions for how to use the instrument; i.e., three weeks in one room, one week in each of three rooms, etc. It also contains a typical graph and statistical summary chart. The logger is loaned for a period of three weeks, after which it is mailed back to the conservation department. The department secretary downloads the data into a PC, and prints both graphs and field statistics. The logger is then cleared and sent to the Field Services Officer for shipment to the next institution on the schedule. The printout is sent to the objects conservator for review and comments as appropriate. In many cases a form letter can accompany the printouts discussing the problems with wide and frequent variations in temperature and/or humidity.

The dataloggers have proved very popular and, like the test kits, are booked months in advance.

PASSIVE MONITORS FOR THE DETECTION OF POLLUTANTS IN MUSEUM ENVIRONMENTS

Cecily M. Grzywacz and Dusan C. Stulik

ABSTRACT

In recent years there has been much concern about air pollutants in the museum environment. GCI has undertaken an extensive Environmental Research Program quantifying pollutants in the museum environment. Dynamic sampling methods were used to detect low parts per billion (ppb) levels of many of these pollutants. Simple, economical passive monitors have been developed based upon the chemistry used in the dynamic sampling modes. Commercially available monitors and a generic passive sampler are discussed. Some passive samplers can be used for direct reading (no analysis required) determination of a number of pollutants. Validation studies are presented along with applications and use of the passive monitors.

INTRODUCTION

There are a number of problems which can arise when cultural property is stored in an environment with airborne pollutants. Leaded coins have been known to deteriorate when stored in highly acidic environments such as those which may develop in oak storage trays or cabinets. Calcareous materials, such as shells, are also susceptible to attack by pollutants. The development of white and gray efflorescence on shells is termed Byne's Disease (Byne 1899) and has been reported at a number of museums including the Bishop Museum in Honolulu, Hawaii and the Queensland Museum, Brisbane, Australia (Agnew 1981). For several decades, carbonyl compounds and organic acids have been recognized in the museum world as corrosive agents for lead objects, leaded bronzes, ethnographic objects, and a variety of other materials (Nockert and Wadsten 1978; Kamath et al 1985; Tennant and Baird 1985; Padfield et al 1982; Hatchfield and Carpenter 1985).

Sometimes the signs of a potentially dangerous atmosphere can be seen on a storage cabinet's hardware. At one museum, the concentration of airborne pollutants was great enough to corrode the internal lock mechanisms of storage cabinets. Although the cabinets were constructed of high quality laminated plywood, the non-laminated edges were exposed inside the cabinets. This resulted in the emission of damaging levels of corrosive volatile compounds, mainly formaldehyde, from the adhesives used in the manufacturing of the plywood. The first indication of the detrimental environment was the corrosion of the locks. This led to a survey of the collection objects in the cabinets. Upon examination, it was apparent that the

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objects also exhibited problems associated with a corrosive environment, such as the development of white crystalline efflorescence on many Asian metal artifacts.

The sources of formaldehyde in a museum environment may be obvious, such as formalin solutions used in the storage of animal or reptile specimens leaking from improperly sealed vessels, or formaldehyde adhesives used in the manufacture of plywood and particle board. However, it is often difficult to discover whether an environment contains potentially harmful pollutants, as well as to identify what the pollutants are and to pinpoint their sources. Therefore, simple qualitative tests such as the "lead coupon" test have been used to obtain a general sense of whether airborne pollutants are present. The conservator simply exposes a clean strip of lead in the suspect environment. At designated times, the strip is visually examined for the development of a gray-white efflorescence. If such surface corrosion occurs on the lead test strip, the curator or conservator is alerted to the potentially damaging environment and can seek mitigation methods. However, such tests are only an indication of the environment in singular locations, and they do not identify the antagonistic pollutant. Due to the increasing awareness of pollutants in the museum environment, the Getty Conservation Institute (GCI) became interested in going beyond this simple pollution indicator test and in finding a way to quantitate levels of formaldehyde and other carbonyl compounds.

ENVIRONMENTAL RESEARCH PROGRAM

GCI's Environmental Research Program developed a five point strategy for pollutant control:

- Develop an *analytical method* capable of detecting the levels of specific classes of pollutants found in museum environments.
- Conduct a *survey* to determine the baseline levels of pollutants.
- Determine *material damage functions*. At what pollutant concentration does detectable damage occur on organic and inorganic materials.
- Identify or develop economical *passive sampling devices*.
- Discover and validate *mitigation methods and technologies*.

The first two objectives for formaldehyde have been completed (C. Druzik and Taketomo 1988; C. Druzik et al 1990), the materials damage research has been reported (Striegel 1991), the mitigation research is work in progress and the passive sampling devices are the subject of this paper.

BACKGROUND RESEARCH: SURVEY OF INDOOR-GENERATED AIRBORNE CARBONYL POLLUTANTS

In the late 1980's, GCI conducted a survey of airborne carbonyl pollutants at 17 participating institutions from the East Coast to the West Coast, including Hawaii. Nearly six hundred air samples were collected from almost 200 sites within these institutions. This survey provided important baseline pollutant-concentration data for formaldehyde, acetaldehyde, formic acid and acetic acid. The emphasis of this paper is on formaldehyde which was the most prevalent airborne pollutant detected.

Before reviewing the results of the museum survey of indoor generated airborne carbonyl pollutants the following reference levels should be considered:

In a typical US home of wood and particle board construction with no urea-formaldehyde foam insulation the typical concentration of formaldehyde is 30 parts per billion (Gammage and Hawthorne 1985).

The outdoor concentration of carbonyl pollutants depends on climate and weather conditions. For Southern California, where the majority of the participating institutions were located, the outdoor ambient carbonyl concentrations are in the low ppb range (Grosjean and Fung 1984, Grosjean 1988, 1991):

formaldehyde:	1-29 ppb
acetaldehyde:	1-13 ppb
formic acid:	1-8 ppb
acetic acid:	2-10 ppb

As a reference for "clean air" or an ultimate baseline level, consider the concentration of formaldehyde detected in the troposphere, 0.4 ppb (Seinfeld 1986) and the concentration of carboxylic acids detected in arctic air, 0.1 ppb (Talbot et al 1988).

The concentration range of formaldehyde detected at the seventeen participating institutions was from less than 0.2 parts per billion (the detection limit of the analytical method) to 1400 parts per billion (ppb). A summary of the survey statistics can be found in Table 1, and the distribution of carbonyl concentrations detected is presented in Table 2. The median concentrations of carbonyl pollutants was 6-12 ppb. Examination of the distribution of pollutant concentrations revealed that the majority of the sites sampled had concentration less than 50 ppb, only 10-15% of the sites sampled had concentrations greater than 50 ppb. Furthermore, the majority of the samples with "high" (>50 ppb) concentrations of formaldehyde were from areas with little air circulation, such as inside display cases and storage cabinets, and all locations with concentration in excess of 100 ppb were display

cases or storage cases. This is not to say, however, that all display cases and storage cabinets had high levels of formaldehyde or other carbonyl pollutants; that would make our task too easy!

TABLE 1: Survey Statistics:
GCI Survey of Indoor-Generated Carbonyl Pollutants

	<i>Formaldehyde</i>	<i>Formic Acid</i>	<i>Acetaldehyde</i>	<i>Acetic Acid</i>
<i>Median</i>	12	6	8	10
<i>Mean</i>	42	14	23	32
<i>Minimum</i>	<0.2	<0.3	<0.2	<0.5
<i>Maximum</i>	1400	290	850	1600

TABLE 2: Distribution of Concentrations:
GCI Survey of Indoor-Generated Carbonyl Pollutants

<i>Concentration Range (ppb)</i>	<i>Formaldehyde</i>	<i>Formic Acid</i>	<i>Acetaldehyde</i>	<i>Acetic Acid</i>
< 19	113 (66%)	143 (83%)	137 (80%)	112 (65%)
20-49	33 (20%)	19 (11%)	27 (16%)	35 (20%)
50-99	12 (7%)	6 (3%)	2 (1%)	14 (8%)
100-500	11 (6%)	4 (3%)	4 (2%)	9 (5%)
> 500	3 (2%)	0	2 (1%)	2 (1%)

From the survey, it was learned that formaldehyde is not ubiquitous. In areas where formaldehyde concentration was high, this could be explained as originating in the types of building materials used, the quality of ventilation as well as the age of the site. It is well known that new plywood and particle board manufactured with urea-formaldehyde resins, for example, can produce copious quantities of formaldehyde (Meyer 1979; Grzeskowiak 1988). If the area is not well ventilated, the pollutant concentrations build up. As the material ages, however, emissions decrease.

PASSIVE SAMPLING DEVICES FOR AIRBORNE FORMALDEHYDE

The goal at the outset of the Passive Monitor Project was to identify passive sampling devices (PSDs) which would be used to detect single digit part per billion levels of pollutants or identify passive samplers whose technology could be stretched to achieve the necessary low limits of detection. In the first phase of the project, the emphasis was on evaluating formaldehyde PSDs

developed commercially. Not only was the conservation community concerned about formaldehyde, but it was recently added to the State of California's list of carcinogenic compounds. The interest in detection of formaldehyde in the work place was advantageous for our project, as there were a number of products on the market for passive detection of this pollutant.

Among the products explored in our study were Sensidyne and National Draeger detector tubes. Detector tubes are pollutant specific. These sorbent tubes are attached to dedicated manual pumps, and a specified number of air strokes are pulled through the tube. In this way, a known volume of air is sampled, and the pollutant concentration can be directly determined based on a color change of the sorbent and the scale on the tube. These formaldehyde detector tubes were not feasible for use in detecting the low concentrations of formaldehyde seen in the museums; they are designed for measuring much higher levels of formaldehyde. While high ppb levels of formaldehyde in museums could be detected by increasing the number of strokes through the tube, the number of strokes required to detect low concentrations of formaldehyde was impractical.

A number of dosimeter type badges developed in response to OSHA and ASHRAE limits on formaldehyde exposure in the work place were also tested. Like the detector tubes, these monitors were designed for much higher formaldehyde concentrations than were present in museums. The detection limits of these badges were two orders of magnitude greater than formaldehyde concentration typically found in galleries and storage areas. We also looked at 3M-brand™ Formaldehyde Monitor and DuPont's ProTek™ badge, both of which were not sensitive enough. Neither Air Quality Research, Inc.'s PF-12 Formaldehyde Monitor nor the Bacharach AirScan™ formaldehyde exposure monitors were good candidates for use in museum environments due to reproducibility and exposure requirement problems.

Finally, we tested the GMD 570 Series Formaldehyde Dosimeter badge. The initial tests were promising, and a passive sampling device validation protocol was developed. Each potential passive sampler was subjected to the following tests:

- Detection Limits
- Reproducibility
- Percent Recovery
- Comparison with Active Sampling
- Interference Studies
- Effects of Low Air Velocity
- Field Tests

Detection Limits: Because the selection of the passive sampling device was for the measurement of museum environments where the concentration of pollutants may be low, it was necessary to ensure that a potential passive sampling device (PSD) was effective at the desired level, in the range from 5 ppb to 1500 ppb for formaldehyde.

Reproducibility: Reproducibility was confirmed to establish the validity of using a limited number of PSDs (frequently only one) at a particular location.

Percent Recovery: The amount of analyte recovered when the passive sampler was exposed to a known amount of pollutant was determined. A PSD was spiked with a known amount of analyte, and compared to the amount of analyte recovered during the analytical process. This is a measure of the analytical method.

Comparison with Active Sampling: The passive sampling device was compared with a standardized active sampling method to further validate its use.

Interference Studies: The badge's response to the target pollutant in the presence of potential interferences was studied. Because the museum environment consist of many different chemical species, interference studies were conducted to determine any substantial positive or negative interference from other pollutants.

Effects of Low Air Velocity: As noted before, locations with the highest concentrations of pollutants were the sites with little or no air circulation, such as display cases. Hence, the PSD's effectiveness in a sealed case with no air circulation was tested.

Field Tests: Finally, the validated passive monitor was tested in the field at a museum.

The GMD formaldehyde dosimeter badge performed very well in the validation tests completed to date. The detection limit was determined to be 5.6 ppb/hour. This translates to 0.2 ppb for a twenty-four hour exposure. The reproducibility of the badges was found to be 95-98%; i.e., the variance among six GMD badges was only 2-5%. The percent recovery was 99%; all of the analyte added to the badge was recovered. When the badges were compared with the active sampling method, the ratio of the amounts of formaldehyde detected was 1.13; in other words, the badges saw 13% more formaldehyde than was detected by active sampling. The difference in the amount of formaldehyde detected in a still-air case when compared to a case with high air circulation was 20%. While this seems high, the US Environmental Protection Agency allows a 20-30% difference to be a reasonable result when comparing active and passive samplers. The chemistry of the badges is very

selective. There were no interferences with typical atmospheric pollutants. Field tests have been successfully completed at three museums.

There are a few cautions when using the GMD badges. The badges must be stored in a freezer, and they should be used within 6 months of purchase. This is beyond the date specified by the manufacturer, but they incorporate a large margin of safety. The badges can be exposed 24-48 hours; with any longer exposure periods, one runs the risk of overexposing the dosimeter badge. The badges should be analyzed within one month after exposure. GMD Systems, Inc. does provide economical analysis; however, they can take a month to report the results. Because of this time delay, the exposed badges should be returned for analysis as soon as possible after exposure. Care must be exercised when placing the badges inside a case or cabinet to maintain the integrity of the internal air quality. One cannot leisurely place the badge inside a cabinet or case, or in a very short time, there will be complete air exchange and dilution of the internal air with room air. Rather, one must open the case minimally and "slip" the badge into the case or cabinet. Fortunately, the badges are very thin, and this is easily achieved. Thus, a GMD dosimeter badge can be used to determine levels of formaldehyde in museum environments.

GMD 570 series formaldehyde dosimeter badges are available from GMD Systems, Inc.; Old Route 519; Hendersonville, PA 15339 USA; (412) 746-3600. The part numbers are 570-010 for the badges only and 570-050 for badges with prepaid analysis, at a cost of \$100 per 10 package and \$400 per 10 package, respectively (as of June 1991). The badges come with instructions for exposure and storage. There are also explicit analysis instructions for those individuals who have access to an analytical laboratory equipped with a high performance liquid chromatography (HPLC) system.

FUTURE WORK

The Passive Monitor Project and the search for mitigation technologies continues. GCI plans to identify or develop passive sampling devices for ozone, nitrogen dioxide, hydrogen sulfide and sulfur dioxide within the next year. With the increasing awareness of indoor air quality, many companies are developing passive sampling devices for these pollutants. It is hoped that we will be able to recommend direct-reading passive samplers or samplers that require no special analysis, much like litmus paper for the testing of pH.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Daniel Grosjean and Associates for technical contributions to the validation of the GMD passive sampler, Karen Cole for her technical assistance and Karen Sexton-Josephs for her assistance in the preparation of this paper.

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An Integrated Approach to Reducing Concentrations of Indoor-Generated Pollutants

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ABSTRACT

Air quality within museums and historical houses, at any one time, represents the sum total of all pollutants coming in from the outside environment plus all pollutants generated within, minus the sum of all processes which extract both. Therefore, indoor air quality is a dynamic process that varies not only by hourly, daily, weekly, and seasonal patterns but also as a function of facilities usage, exhibition schedules and maintenance. It is this ever changing character which makes estimation of air quality, particularly difficult to determine, and has coined the concept of the "building ecology" approach to indoor air quality.

For pollutants generated indoors, there are two broad classes of mitigation strategies - *chemical approaches* - which eliminate reactive species by adsorption, absorption, or chemical transformations, and *mechanical approaches* - which dilutes the concentrations of reactive gases or act as barriers that slow down their release rates. Since mechanical approaches are relatively simple to understand and easy to implement, they should be readily integrated into any abatement plan.

Introduction

In theory and practice, it is possible to build a display case or storage cabinet that is made of inert materials, is self-cleaning, buffers its internal relative humidity and provides some protection against photochemically-induced deterioration (Preusser, 1989). But in reality, there are probably thousands of microenvironments just in the United States alone that were built before these requirements were thought necessary or desirable. It was seldom imagined, for example, that some metals, shells, minerals and ceramics could be quickly corroded by organic acid vapors produced in these enclosures. As more attention is paid to this potential risk, more damage is inevitably found. In most instances, these cases or storage facilities cannot be feasibly replaced - what then to do? Is the situation hopeless?

Fortunately there exists a substantial body of knowledge on pollutant control which can be directed to retrofitting these types of microenvironments. Some of the "fixes" I'll suggest will be difficult to aesthetically implement and others might seem counterintuitive - like encouraging leakier display case rather than better sealed designs. Nevertheless, if a problem is known or suspected to exist, the basic approach described here is sound and will, in theory and in the laboratory, work well. The considerations I'll offer, will also relate work done by previous conservation researchers with the best of the recently developed mathematical models taken from the environmental engineering field.

Nazaroff and Cass (1986) developed models which predict pollutant concentrations indoors reasonably well. The elements of their treatment included flow rates between the museum building and outside and through the building's air conditioning plant; loss of pollutants to different types of walls and wall coverings; total surface area, volume; and the better known chemical reactions which take place in the gas phase, with and without additional photochemical inputs. Many of the observations recommended here stem from factors in this model which have not been specifically discussed in the conservation literature previously.

One of the realities of museum climatology is that gases move from areas of high concentration to those of low. This is true whether we are discussing water vapor, inert gases or air pollutants. This is usually overcome with respect to moisture by continuously supplying or subtracting water vapor. The active approach is by adding humidification or dehumidification in air conditioning plants or passively

incorporating silica gel in display cases. In inert gas environments, a combination of impermeable materials and tight seals tend to be the time-tested solutions. But when it comes to controlling air pollution, the problem quickly becomes more complicated.

Figure 1 illustrates one solution whereby the principal line of defense is the museum shell backed up by filtration in the Heating, Ventilating, and Air Conditioning system (HVAC). Outdoor pollutants that still get into the building react with wall coverings resulting in virtually no outdoor pollutant gaining access to display cases. In this solution, the display case or storage rooms themselves are minor defense mechanisms and it is preferable to have them as leaky as possible, using the building to dilute and dispatch indoor pollutants that may be emanating from within.

Figure 2 is the other solution, one more easily applied in historical houses or buildings with no air filtration. Here the display case or storage vault is the principal defense. The museum shell is leaky because natural ventilation dominates, there is no loss of pollutants to a mechanical plant, and surface loss becomes the major protection mechanism outside storage and display. In this scenario, the physical barrier of the microenvironment is very important as is the ability of the microenvironment to control any pollutants that builds up within.

Cass et al.(1988) illustrates some of these points. Figure 3 shows what can be achieved by combining a chemical filter media while simultaneously reducing the rate at which outside air is taken into the building. Here, showing data for ozone in an air conditioned museum in Claremont, California, we see that lengthening the time for air to exchange by a factor of ten, results in a similar reduction in indoor concentrations. By slowing the rate highly polluted air is dragged into the building, other reactive surfaces, air chemistry and multiple passes through the HVAC system can deplete ozone concentrations in competition with air objects. Figure 4 shows that in an environment without chemical filtration and where natural ventilation dominates, the concentration inside a restricted air exchange microenvironment (here a display case with relatively wide gaps) can be quite low compared to its surrounding air.

In a different type of example, Passaglia (1987) discusses how document storage boxes can be either protective or non-protective to sulfur dioxide intrusion, depending

upon whether or not SO₂ has an opportunity to react with the walls of the box, or simply enter through gaps in box construction.

A Closer Look At Microenvironmental "Fixes"

Relationship of Air Exchange to Concentrations

Mathematical models reduced to their most laconic form say that: indoor air pollution is the product of all processes which add pollutants and all those which subtract them. Each and every processes has a unique rate step, which may or may not be constant. Processes which add or subtract pollutants very slowly are less important than faster ones, and if any single fast additive process can be matched by a fast or faster subtractive one, pollutant concentrations will be displaced to lower levels. If we wish to match a release rate for formaldehyde with fast ventilation rates, it is easy to engineer very much faster subtractive processes (ventilation) that can dominate the slower additive ones (formaldehyde release). On the other hand, it's more commonly found that very slow, subtractive processes (diffusion) are completely dominated by faster pollutant release rates (Passaglia, 1987). The exact pollutant, its sources, sinks and the construction of the case or storage area, all work together to establish the actual concentration level.

Virtually all examples of phenomenon like "matburn" and other forms of acid migration or lignin decomposition products transferring to higher grade papers in sealed frames, probably would not occur in frames where a laminar air flows parallel to bevelled mat cuts, whisked these products out the back of the frame. While such micro-, dare I say, nanoscaled HVAC systems for picture frames seems ludicrous, it's a similar instinct that drives the idea and practice by paper conservators of leaving open the corners of Mylar encapsulation.

Although it would not be feasible to use high ventilation rates to protect objects in sealed frames, there are numerous situations like cabinetry where high ventilation rates are probably responsible for a lack of visible deterioration, provided however, that the next larger contiguous air volume is not more polluted than the smaller or adjacent one. The difficulty in proving that high ventilation rates are working alone, is that it's not as easy to say why something is not deteriorating as it is to say why it is.

Cecily Druzik (1991a) found in her extensive museum sampling study, that generally, the concentration of formaldehyde predictably followed the rates of air

exchanges within galleries, storage rooms and display cases (Figure 5). As the air exchange rate increased, the formaldehyde concentration decreased: galleries had the lowest concentrations, display cases, the highest, and storage vaults were intermediate. While aldehydes and organic acids are normal components of urban air pollution, their outdoor concentrations are usually not as high as those often found to cause damage indoors and much lower still in non-urban areas.

Effects of Sacrificial Surfaces

Since we know much more about the behavior of outdoor-generated pollutants than indoor-generated ones at this point, I'll illustrate the importance of pollutant loss to walls using ozone, sulfur dioxide, nitric acid vapor, and nitrogen dioxide, then proceed to show how it works with indoor-generated pollutants.

High losses of sulfur dioxide have been observed in museums (Hackney, 1984) and in laboratory tests (Parmar, 1991a,b). Hackney found concentrations levels only 25% the outdoor levels. Parmar's loss rates for SO₂ on Plexiglas alone, a material considered to have relatively low reactivity, were the highest of any pollutant he examined. Finally, many have observed the very high rates of SO₂ sorption shown by paper and other cellulose (Williams II, 1990; Edwards, 1968). Nitric acid is equal to, if not greater, than sulfur dioxide in its loss to walls. So great is this loss on nylon for example, it can be quantitatively removed this way. J. Druzik et al. (1990) presented data in which ozone concentrations ranged from high, medium or low in rough correlation to the air exchange rates of the building. Houses had low levels, air conditioned building **without** chemical filtration were intermediate, and highly ventilated structures were the highest. Nitrogen dioxide, on the other hand, has lower reactivity than the other pollutants just mentioned and accordingly, it's typically found in higher concentrations indoors (Hughes, 1983; Hisham, 1989). In all these instances, loss of pollutant to surfaces was the dominant reason for lower indoor/outdoor concentration ratios.

Turning to indoor-generated pollutants, Figure 6 illustrates what happens when other materials are present in competition with cultural artifacts for pollutant scavenging. Line 1 is of a silver object in a Plexiglas case where the half-loss time for hydrogen sulfide is 6.8 hours. By adding another 700 square centimeters of silver surface, the half-loss time is reduced to 1.82. By comparison, line 3 is for 20 grams of activated carbon in an empty case and shows a half-loss time of 0.88 hours. For

either instance, 2 or 3, most of the hydrogen sulfide would have ended up harmlessly on surfaces other than the silver object you wanted to protect. Silver protection with colloidal silver dispersed in paper or cloth work this way.

Padfield's suspicion that buffered lining papers or boards would be generally helpful in drawers and cabinets follow from this phenomenon (Padfield, 1982)..

Effects of the Surface/Volume Ratio

Figure 7 demonstrates a very subtle aspect of enclosures - how just the surface-to-volume ratio alone can effect the rate at which a pollutant is lost to walls. Here line 1 represents the concentration decay of ozone in an empty display case. By placing a smaller box within the larger case, we increased the surface area relative to the free volume. This resulted in a decay rate almost twice as fast than that of the more voluminous case. One of the reasons, ozone concentrations decrease so quickly in the Fenyes Mansion (J. Druzik, 1990) is that, like private homes, it has a remarkably high surface area; the rooms are small, hallways long and narrow, convoluted Victorian wood molding everywhere, and plenty of books, tapestry and cloth upholstered furniture. Here we have a combination of high surface area and many types of reactivities.

Coatings and Barriers on Emitting Surfaces

Figure 8, taken from work carried out by Hatchfield and Carpenter (1987) at the Harvard University Art Museums, plots the efficiency of five coating systems applied to birch-veneered particleboard as barriers to formaldehyde emission. A reduction in emission in the range of 60-90% seems quite reasonable for paints and varnishes. Still better yet might be a polymer/foil laminate or a combination of strategies. John Burke (1991) has researched the area of solid film barriers extensively, as have others, and has identified a few that would work if all else fails.

Chemical Sorbents

Of course the most effective means of "passive" control is carried out with chemical sorbents, and Figure 9 radically displays it. In this study from Parmar and Grosjean

(1991a), equivalent weights of potassium permanganate on an alumina substrate and crushed activated carbon are compared in terms of their sulfur dioxide removal rates. If this experiment were duplicated with a "active" system (say a small cartridge of sorbent on a fan hidden below the decking of a display case or a free-standing unit in storage) the effects would be much more dramatic.

Remove the Offending Materials

Frequently it is possible to remove an offending material and replace it with a more stable one. Wool coverings with a sulfur-based dye comes immediately to mind, as does the replacement of particleboard with either of the two non-formaldehyde containing substitutes - but beware. All wood can and will liberate acetic acid, so even this step should be backed up further with barriers and coatings. We know enough at this point to treat, as equally dangerous, formaldehyde, acetaldehyde, formic and acetic acids.

Combinations of Various "Fixes"

As a qualitative insight then, Figure 10 shows a hypothetical display case and pollutant which have reached a steady-state equilibrium. In this figure, the display case has achieved a concentration of 800 parts per billion. (For the above mentioned four pollutants, concentrations this high were very rare in C. Druzik's surveys in the United States but common in Europe according to Norman Tennent (1991). However, it could equally be 8 ppb for acetic acid or 80 ppt for hydrogen sulfide.) Simply by doubling the air exchange rate, increasing internal reacting surfaces and effecting a reasonable reduction in emissions, we can reduce exposure concentration and possibly the rate of damage by a factor of twenty. This is even before any form of surface protection is given to a vulnerable material, i.e. B72 or Incralac on copper.

I hope to be able to convey the idea that, by combining a series of mechanical and chemical abatement techniques, independent of knowing any detail of what pollutants exist within a display case or storage area and in ignorance of which materials are sensitive, we can predict general trends in concentration reduction. And this is, the heart and soul of preventive conservation.

Words of Caution!

It should always be remembered that there is no such thing as a “threshold limit value” for objects. Artifacts don’t heal; they have no tolerance beyond their own compositional vulnerability. Therefore, one cannot make any recommendations for acceptable lower limits. If you reduce the concentration by ten-fold you may or may not reduce the rate of deterioration in a similar manner, but, there is little or no credible literature indicating a point where deterioration stops. Corrosion of metals, identified as formates, has been observed even at low parts per billion levels. The conservation literature is resplendent with “suggested museum levels” and it’s an easy way to get a fast publication, but ultimately the lowest attainable, economically-reasonable concentrations based upon our best models, applied by competent practitioners, and peer-reviewed, should be our guideline.

Conclusions and Recommendations

Within the last ten years we have learned a great deal about controlling pollutants within display cases and storage areas. If no problem exists; nothing needs to be done even under the banner of “preventive conservation.”. *But if a degenerative condition can be pinpointed to indoor pollutants, there are a number of mechanical and semi-chemical/mechanical procedures that can be applied. Let us revisit our major corrective steps and add a few additional thoughts.*

(1) Sorbents and Sacrificial Surfaces Lining microenvironments wherever possible with a calcium carbonate-buffered paper or paperboard and the use of activated carbon, as an internal sorbent for pollution were largely speculative recommendations when Padfield made them in 1982. Since then numerous behaviors of these two materials have been quantified by Williams (1990) and Parmar (1991), respectively, and we believe Padfield’s faith has been well founded. However, this area needs considerable future research because we know more about how display materials release pollutants than how they absorb them. Sabersky (1973) for example has done this for ozone’s reactivity towards such materials as cotton, linen, plywood, nylon, etc. but more needs to be done. Reilly’s work on photographic materials clearly identifies a large body of objects that are probably as sensitive to the pollutant as the protection.

(2) Increase Surface-to-Volume Ratios One other advantage not envisioned by Padfield with an acid-free tissue paper used for wrapping or padding purposes, is its effect in increasing the surface-to-volume ratio in tight spaces. This increases the “deposition velocity” of acidic pollutants, some of their precursors, and most oxidants, thereby increasing the loss to surfaces other than those provided by objects of cultural value. Regardless of the chemical mechanisms involved, the result is a drop in ambient concentrations.

(3) Coatings and Barriers Since Catherine Miles’ article in Studies in Conservation on wood coatings for storage and display cases, nothing has replaced two-component epoxy or moisture-cure urethanes as sealants although metal/polymer laminate films still remain the most secure barriers to wood VOCs. Use the solvent swab test early on to determine if cured enamel coatings are cured well enough and monitor the environment anyway. There have been a few painful failures of these systems in the last few years where the manufacturer has denied responsibility. If one is considering purchasing enameled metal, explain your concerns and request or demand a “return policy” if, within a reasonable time period, these types of housings “turn on” their contents.

(4) Increase Air Exchange Rates - Display Cases Air exchange rates in sealed cases are important, but any attempt to seek standardization or find “recommended values” for safe storage, is probably a waste of time. Leakage rates of one air exchange per day have been independently measured by Thomson (1978), Ramer (1981) and Padfield (1982) and are considered average for commonly sealed display cases. While this is slow enough to dampen external environmental fluctuations, it is too slow to insure that internal pollutants won’t damage susceptible contents. Nevertheless, pollutant release rates can never be generalized accurately enough to be trustworthy which is why a fixed recommendation for air exchanges is useless. Increasing air exchange rates from 1 day⁻¹ to 1 hr⁻¹ or even faster is however suggested to mitigate a problem when damage is known to be occurring or sampling has shown a probably cause for concern. Recently, interest in microenvironments with very low or trace leakages has grown (Preusser, 1989). The case developed for the Royal Mummies in the Cairo Museum for example has a 2-3 ppm day⁻¹ leakage rate. These types of cases should not be considered without also considering how the designer intends to monitor their contents or make them self-cleaning.

Re-Evaluate Air Circulation - Storage Areas Reduced air exchanges in storage areas is often advocated because it has certain advantages in terms of energy conservation, fire suppression, keeping out outdoor-generated pollutants, and generally stabilizing climatic fluctuations in temperature and relative humidity. But reduced air circulation does nothing to improve air quality from the standpoint of indoor-generated pollutants, a phenomenon occasionally described as “sick building syndrome.” If a building has activated carbon or permanganate/alumina filter media in the return air supply or is in a non-urban environment, it makes more sense to increase storage area air circulation rather than reduce it, thereby continuously suppressing pollutant levels.

In the event of active corrosion, doors on cabinets restrict air circulation and could be removed. Objects should also be spread out to use up available space. This may not reduce localized concentrations significantly, but even a slight reduction is better than no reduction at all. We inculcate the point that there is no such thing as a “threshold limit value” for objects. All damage is cumulative and therefore all reductions, even very minute ones lengthen the time for accumulated damages to be visible.

(5) Adopt a Passive Monitor Program For both display and storage areas, active or passive monitoring is strongly suggested. Druzik (1991b) has demonstrated that the technologies for passive monitors either currently exists or is just awaiting validation for museum application, before being recommended for inexpensive sampling. The GMD Series Formaldehyde Dosimeter for example has an analytical detection limit of less than 1 part per billion. This is more than adequate for what is needed.

(7) Active Filtration Stulik (1990) has included a cartridge of activated carbon impregnated with catalyst (the same type used in respirator masks) into an air purification device for display cases. This small machine is currently being tested in museum field trials and should be able to “knock down” concentrations over 1 part per million.

(8) Stabilize Contents Regretably, we only think we know how to do this in a few instances.

(9) Know Your Materials Excellent background on dangerous materials and testing have been compiled by Padfield (1982), Hatchfield and Carpenter (1987) and Blackshaw (1979). In addition, compilations of materials testing like those maintained at the Canadian Conservation Institute (1986) or the Getty Conservation Institute (1989), regardless of their limitations, remain invaluable reference sources. Special attention should also be given to products that have evolved as a parallel response to indoor air pollution, such as particleboards that do not incorporate formaldehyde-containing resin systems. Incidentally, plastic bubble wraps should also be watched carefully since tarnishing from these had been previously reported in a regional conservation association newsletter (Chandler, 1982).

As a well-know television personality says, "Keep well informed, and fight back."

Products and Services

Passive Formaldehyde Monitors - GMD 570 Series Formaldehyde Dosimeter Badge
GMD Systems, Inc., Old Route 519, Hendersonville, PA 15339. (412) 746-3600

Charcoal Cloth - Charcoal Cloth Limited, East Wing, Bridgewater Lodge, 160 Bridge Road, Maidenhead, Berkshire, SL6 8DG, England. FAX (0628) 773380
Attention: Mrs. S. Scott, Product Manager

Barrier Films -

Film-O-Wrap 2175, 2176 and 7750, Bell Fibre Products Corporation, P.O. Box 1158, 1 Minden Road, Homer, LA 71040

Marvel Seal 360 and 1177, Ludlow Corporation, Laminating & Coating Division, Columbus, GE 31993

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Figure Captions

- Figure 1 Building where the museum shell and the HVAC filtration provide the principal defense against pollutants
- Figure 2 Building where the inside microenvironments provide the principal defense mechanisms against pollutants
- Figure 3 Ozone concentrations inside the Montgomery Gallery as a function of air exchange rates (Cass, 1988)
- Figure 4 Ozone concentrations inside microenvironments where the principal defense are the glass or Plexiglas walls (Cass, 1988)
- Figure 5 Relationship between formaldehyde concentration, air exchange rate and increased incidence of corrosion (C. Druzik, 1991b)
- Figure 6 Reduction of hydrogen sulfide in a Plexiglas case by including sacrificial surfaces (Parmar, 1991a,b)
- Figure 7 Reduction of ozone concentrations by increasing the surface/volume ratio of the microenvironment (Parmar, 1991a,b)
- Figure 8 Effects of coatings on formaldehyde release from particleboard (after Hatchfield and Carpenter, 1987)
- Figure 9 Effects of chemical sorbents on sulfur dioxide concentrations in microenvironments (Parmar, 1991a,b)
- Figure 10 Effects of four additive steps in reducing the overall concentrations of a hypothetical pollutant in a microenvironment

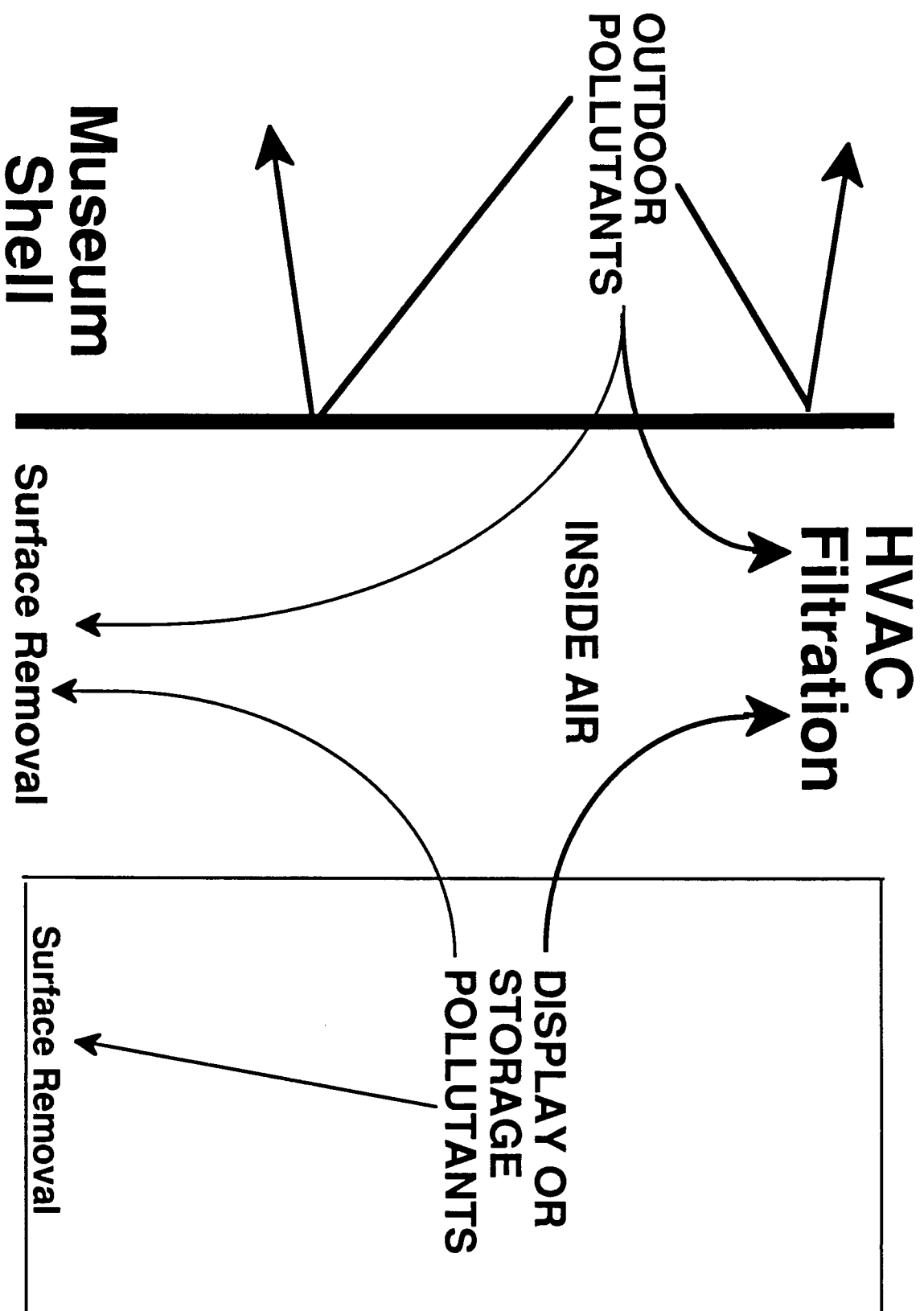


Fig.1.

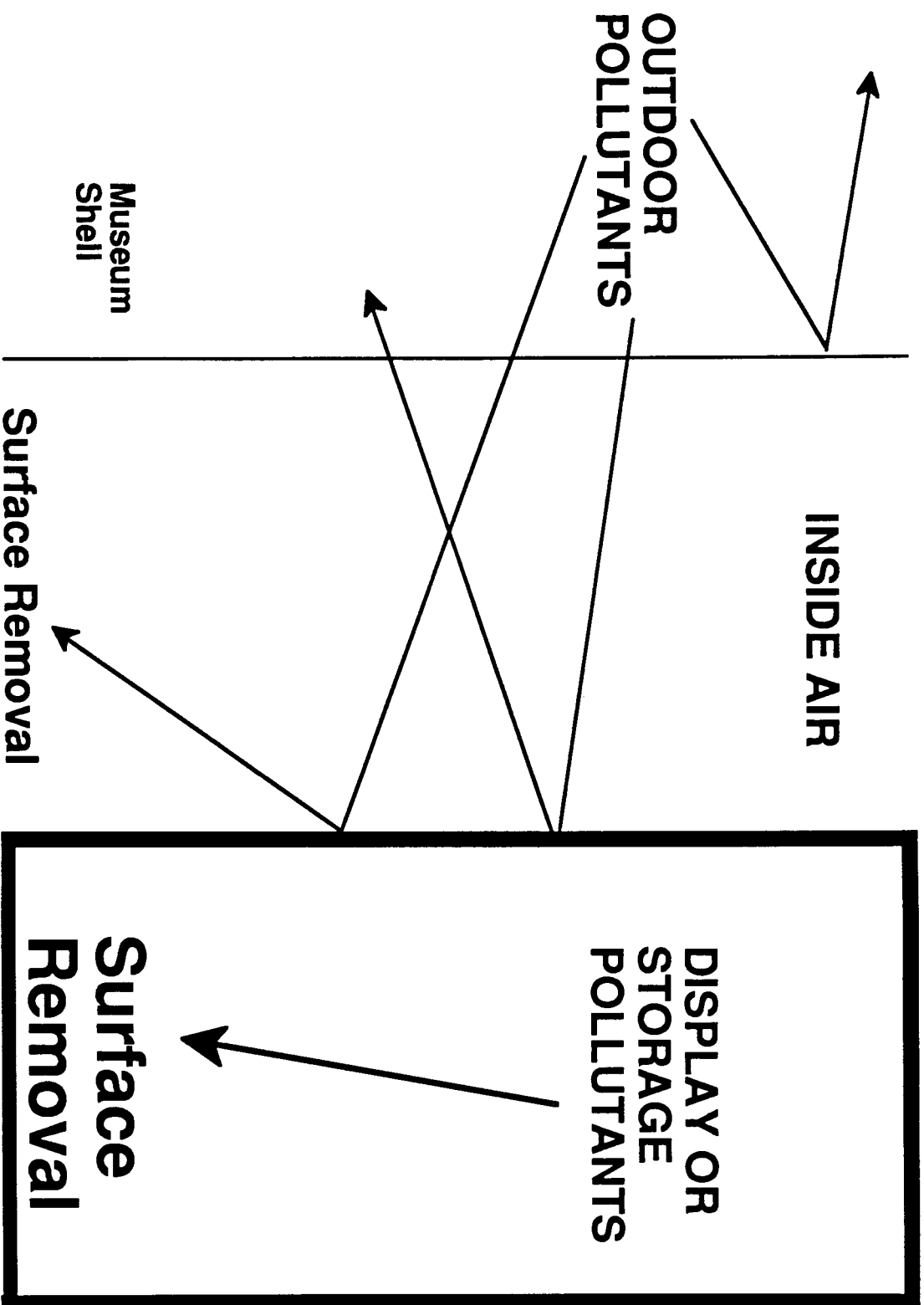


Fig. 2.

MONTGOMERY GALLERY

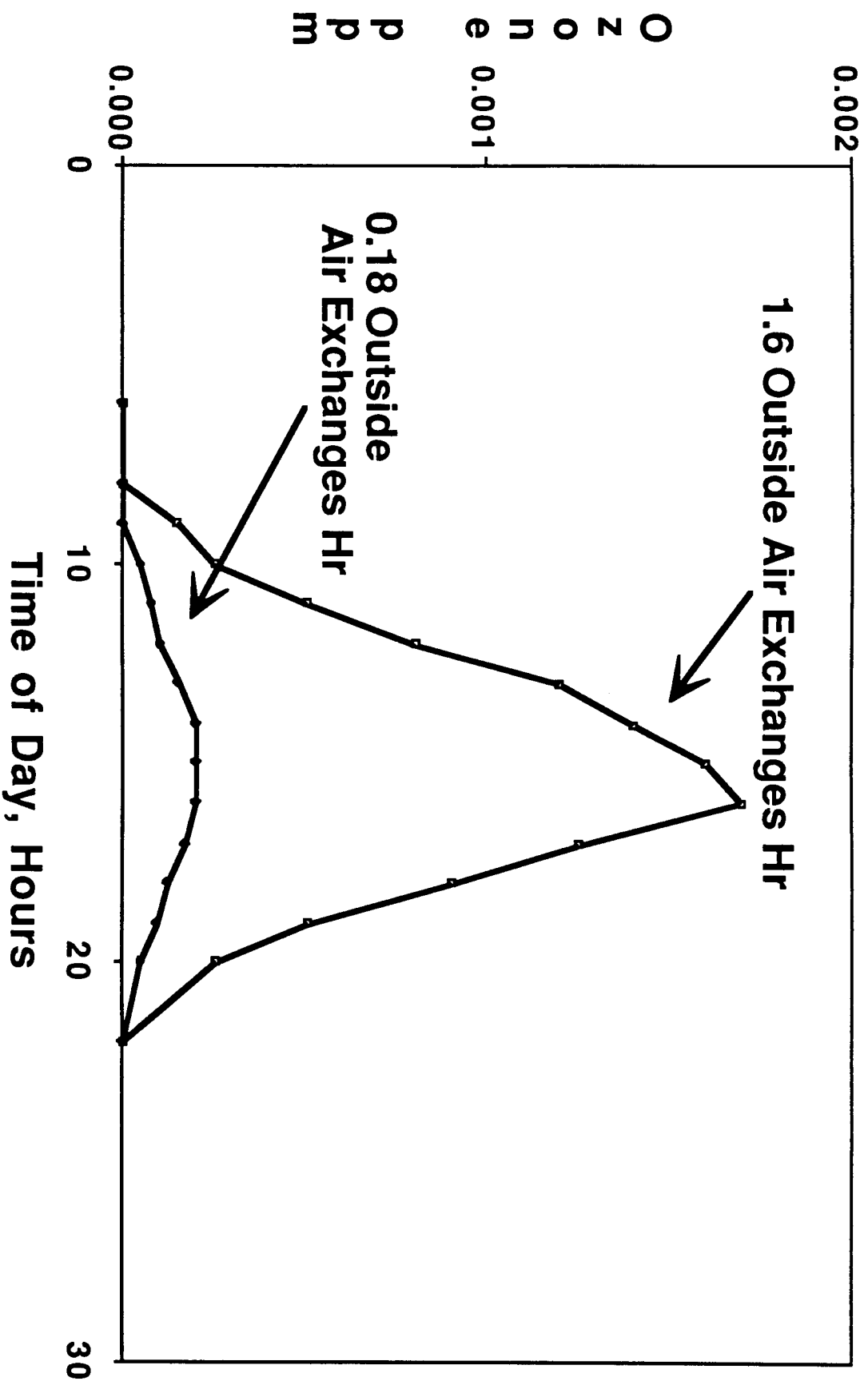


Fig. 3.

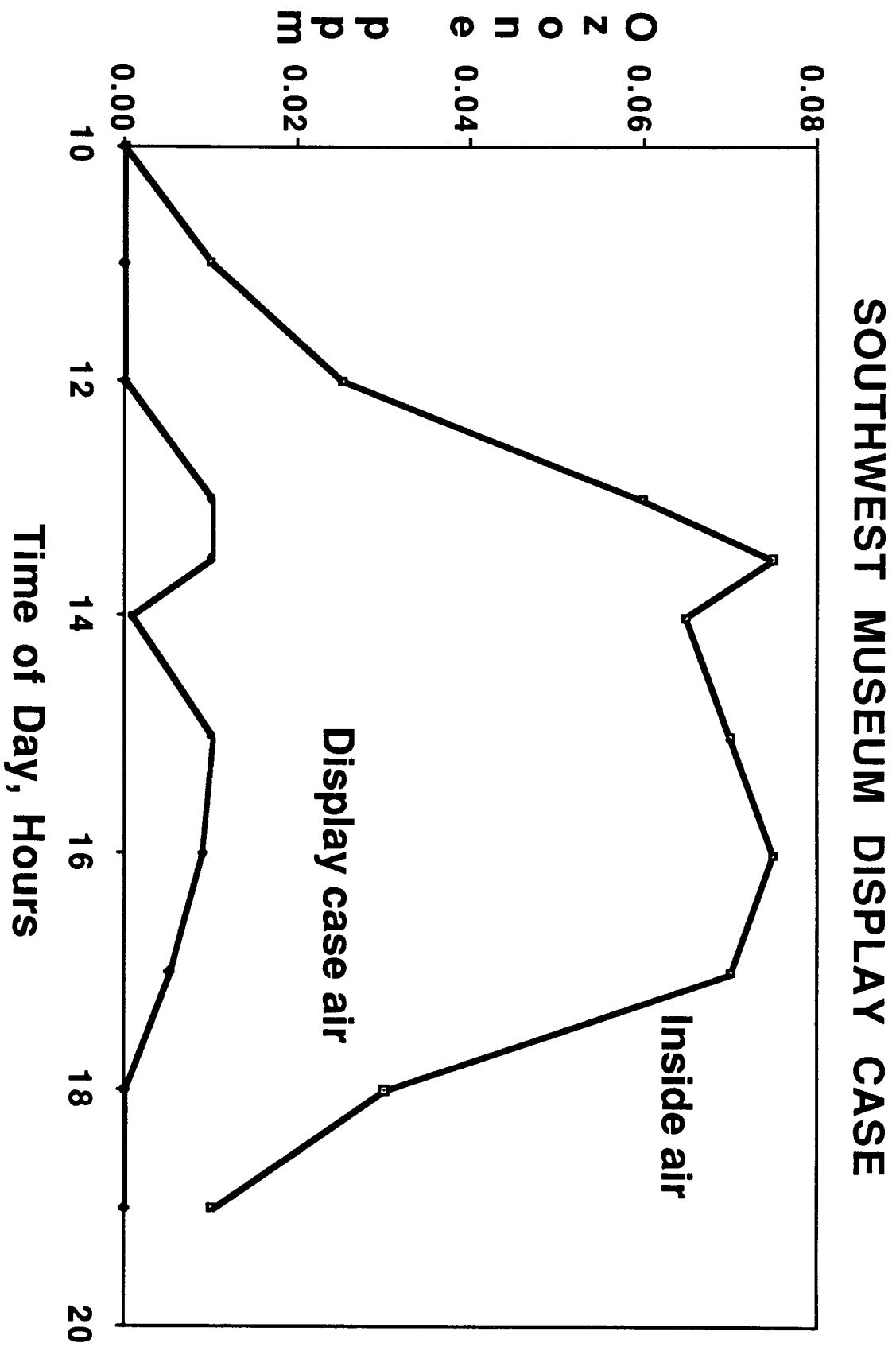


Fig.4.

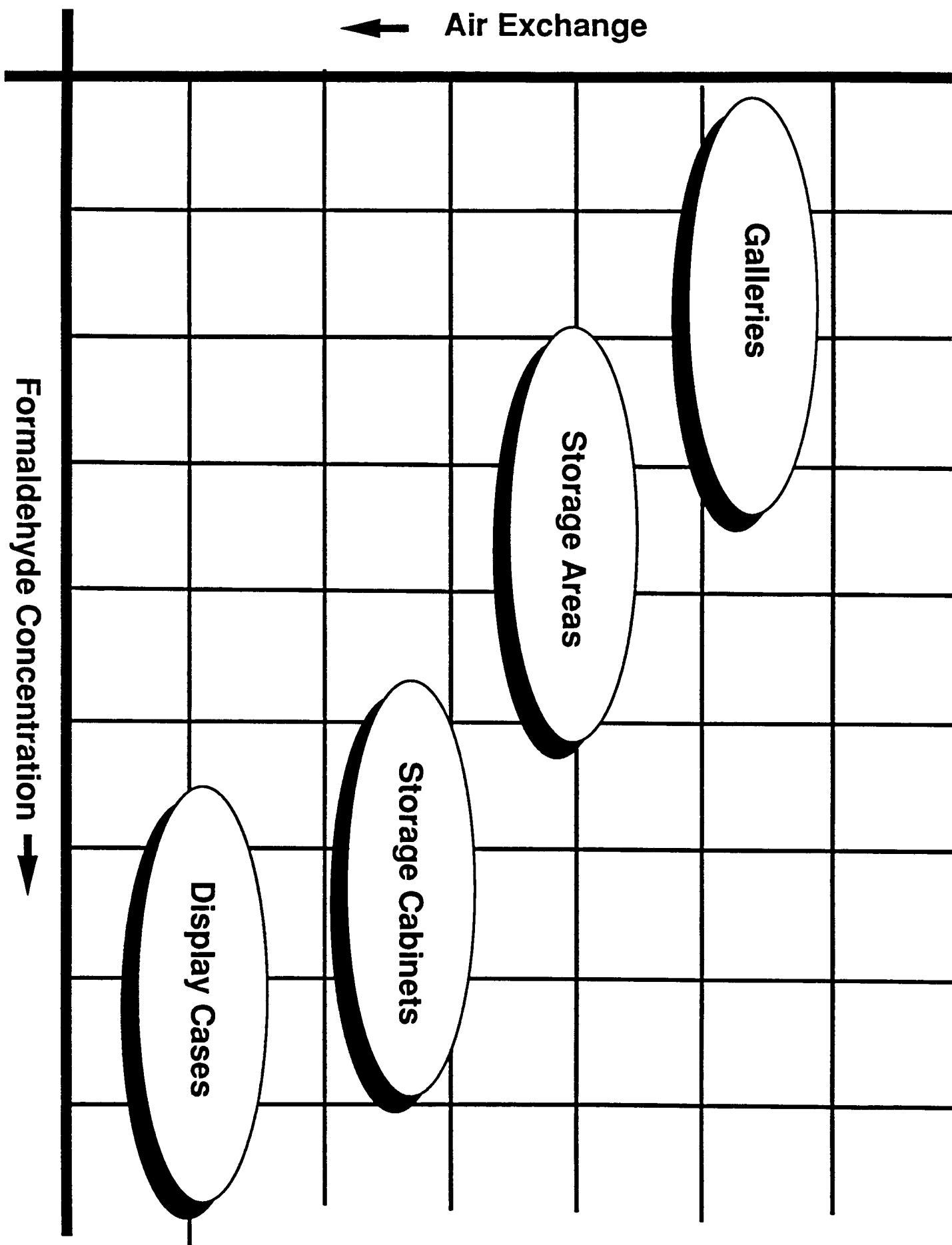


Fig. 5.

EFFECTS OF SACRIFICIAL SURFACES

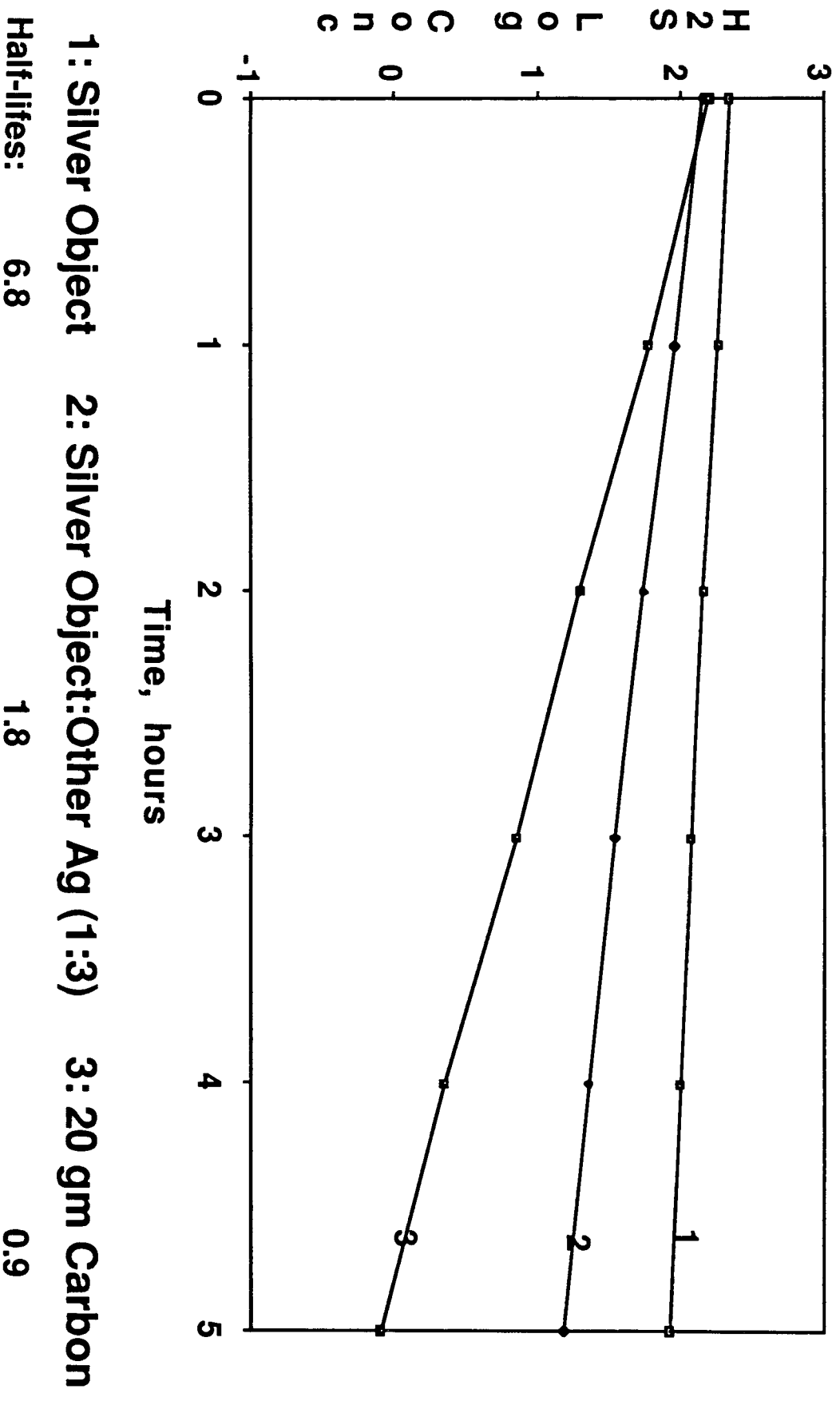


Fig. 6.

EFFECTS OF SURFACE/VOLUME RATIO

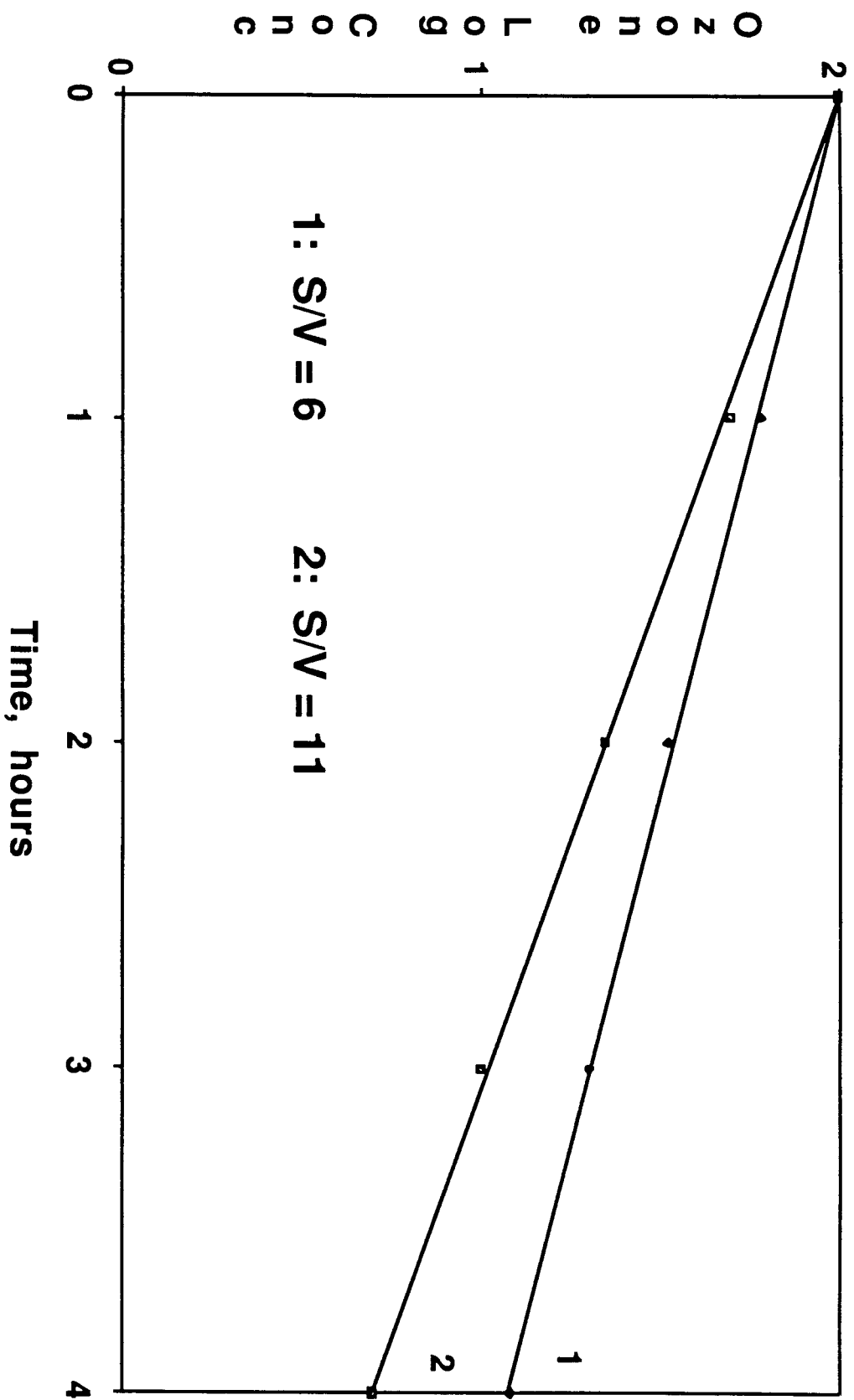


Fig.7.

COATINGS ON PARTICLEBOARD

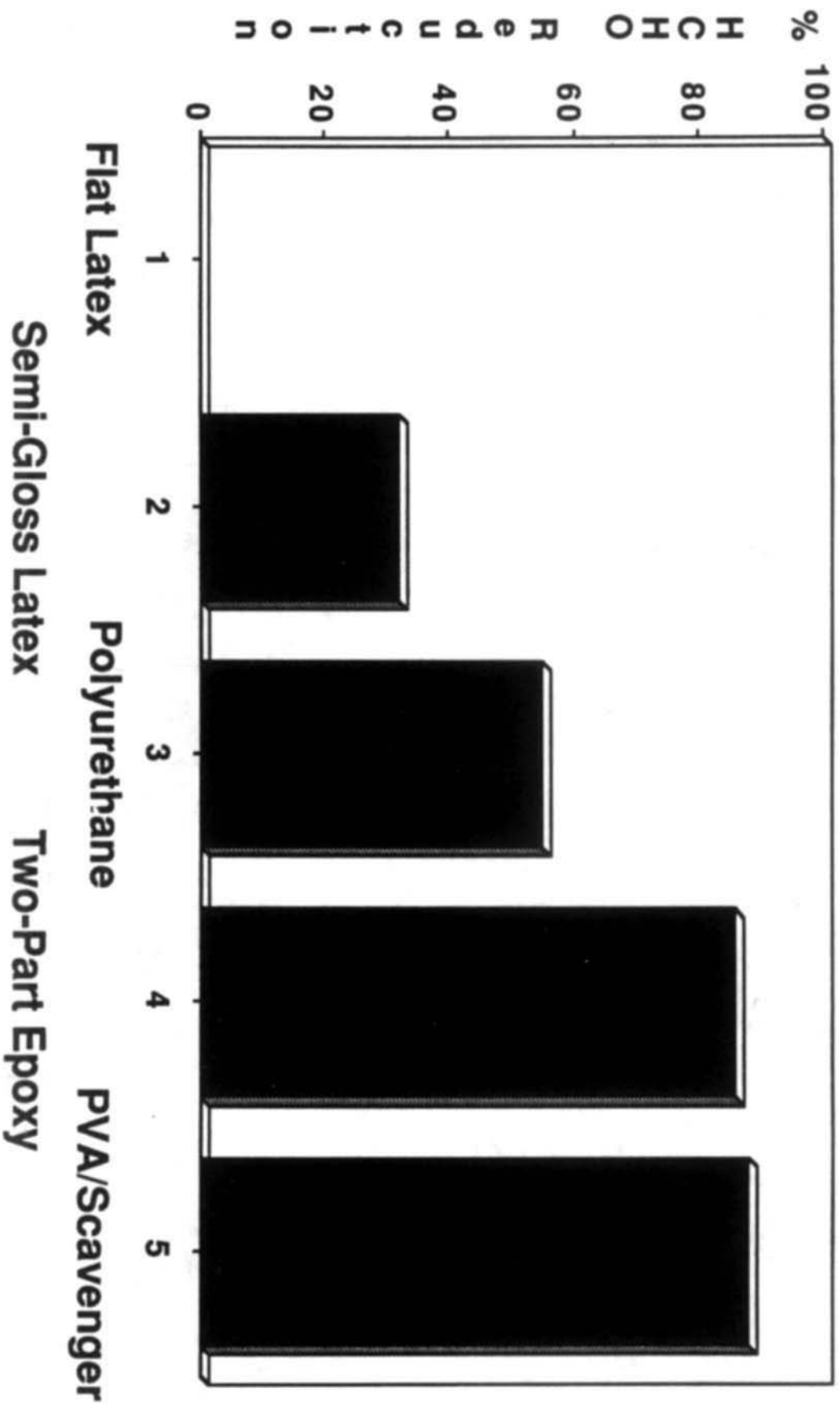


Fig. 8.

EFFECTS OF CHEMICAL SORBENTS

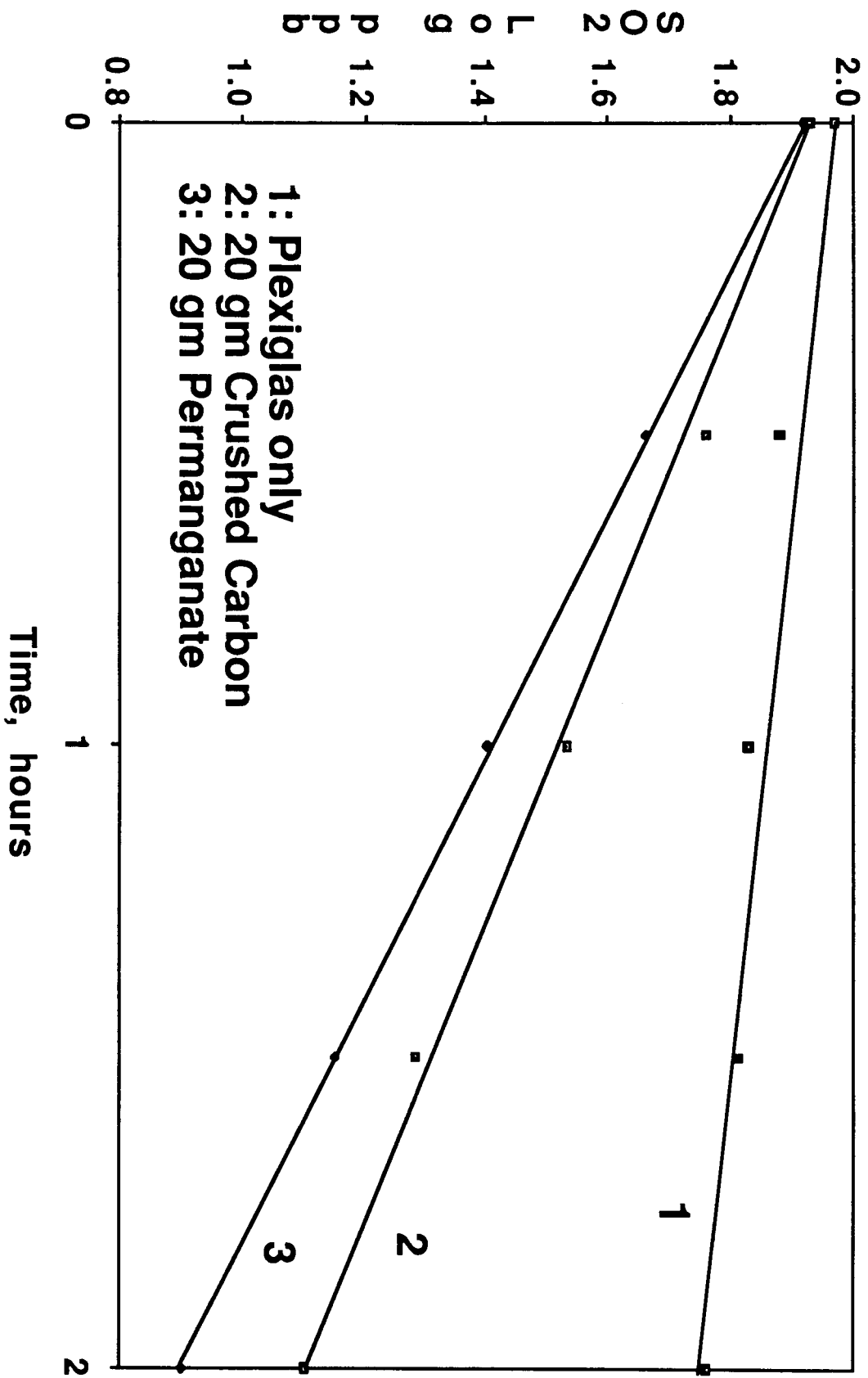


Fig. 9.

Fig.10.

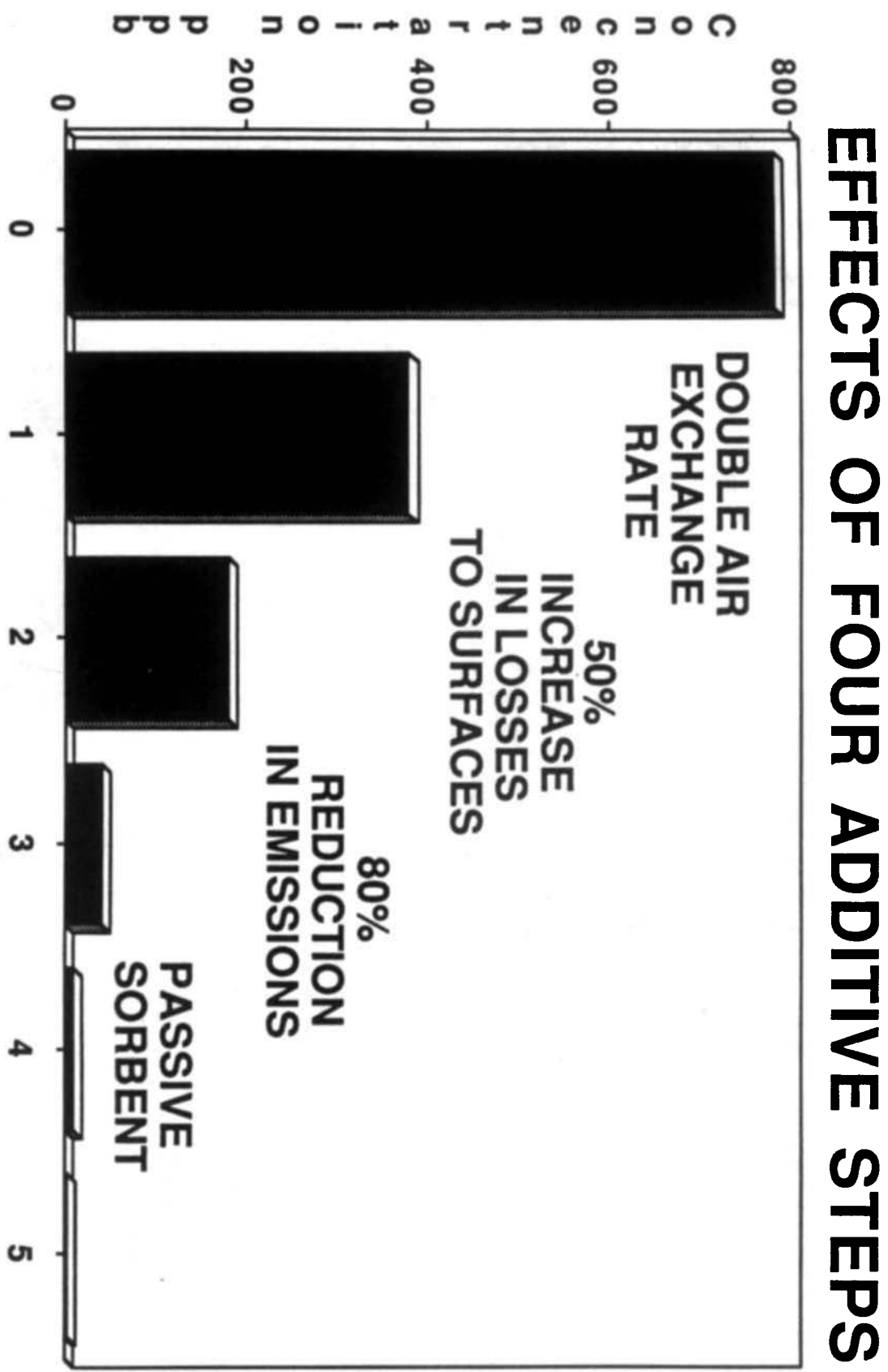


Fig.10.

Shelley Reisman Paine
Objects Conservator

The *Masterworks* Exhibition - A Case Study in Climate Control and the Role of the Conservator in an International Exhibition.

October 13 1990, the Tennessee State Museum in Nashville, Tennessee, opened an exhibit called *Masterworks*, comprised of sixty-one Impressionist and Post-Impressionist paintings from the Bridgestone Museum of Art in Tokyo, Japan. The Bridgestone Museum is a private institution which had made only two previous loans. Nashville was the only venue for this exhibition.

My work on this exhibition began as a consultant retained to solve problems related to the environment should they occur. However, my role in this project changed in some extraordinary ways because problems did occur. Significant changes were made in my role and in my contract. In the process of correcting problems, significant alterations were made in the climate control system. All of these changes were initiated ten days **after** the paintings arrived in Nashville, five days before the exhibit opening.

THE ROLE OF THE CONSERVATOR

Five days before the opening, my initial contract was approved and I began working with Mr. Chiaki Tanaka, the Bridgestone Museum painting conservator and Mr. Tsyuoshi Kaizuka, the assistant curator to solve problems related to the environment. Bridgestone Museum of Art had written into the exhibition contract very specific and narrow acceptable environmental conditions. The Museum was to maintain 70 degrees F and 55% relative humidity within $\pm 2\%$ over 24 hours.

On my first day of work a leak from the janitors closet above the *Masterworks* gallery caused water to drip next to Matisse's "Odalisque with Raised Arms", and coincidentally the relative humidity in the gallery dropped to 37%. I began work with the building staff to begin to correct these problems. Within five days

Shelley Reisman Paine, 606 Fatherland Street, Nashville, Tn. 37206

of the opening, a plan to modify the climate control system to sustain 55% relative humidity was initiated. The pipes in the ceiling were mapped and all sources of water cut off. PVC gutters, painted black to blend with the ceiling, were placed under each pipe, drains were sealed, and doors to the janitors closets and adjacent restrooms and drinking fountain were locked and rekeyed. The single key to these new locks was placed in the building managers pocket. The Matisse was then rehung on the wall and the exhibit opened.

At the time of the opening, a week before Mr. Tanaka and Mr. Kaizuka returned to Japan, Mr. Yasuo Kamon, the Director of the Bridgestone Museum of Art requested that I work for the Museum in a position of authority over the collection in the absence of his Museum staff. I was greatly honored by this request but I was already on contract to the Tennessee State Museum. Further, I felt that the best situation would be for me to work jointly for both institutions. Both institutions agreed to this arrangement but neither could find another Museum which had successfully formed this type of contractual relationship.

The question was taken up by the Attorney General of the State of Tennessee who was the contract negotiator for the exhibition. He met our request with some skepticism and asked me if I could work for two masters. I replied that I only worked for the paintings and that if each institution was only concerned with the well being of the paintings then my work could not be compromised. He considered my position and found a precedent in the construction industry. There is a position for a person who represents both the lender and the owner during the construction of a building. This precedent lead to an amendment which identified me as Representative of the Paintings in the contract between the Tennessee State Museum and the Bridgestone Museum of Art. My work was now directed by the paintings using legal instruments agreed to by both Museums.

THE CONTRACT

According to the amendment to the contract, my authority was defined in a protocol of emergencies. The protocol was a separate document agreed upon by me, the State of Tennessee, the Tennessee State Museum and the Bridgestone Museum of Art. The protocol outlined procedures for all forms of potential emergencies and my authority in each situation. The emergency situations included vandalism, fire and flood, earthquake, security and significant shifts

in the gallery environment. An evacuation plan was included as well as a list of who was called during emergencies and in what order. Everyone on the list, including me had a beeper for 24 hour access.

The gallery environment was a critical component of the original contract between the two museums. The guidelines for the climate were re-stated in the protocol for emergencies. The Tennessee State Museum was to sustain a climate of 55% relative humidity and 72 degrees F. with $\pm 2.5\%$ relative humidity within any given day and $\pm 5\%$ over a month. If the 55% could not be sustained, the relative humidity could be lowered with the permission of the Bridgestone Museum of Art to 50% within the same ranges. If the relative humidity fell below 40% for more 24 hours, then those objects designated "A", extremely delicate paintings which were often unvarnished and unlined would be placed in pre-made Royco envelopes. If a fall in relative humidity was rapid and without reason, then all paintings would be placed in envelopes at 40% relative humidity. At 35% relative humidity all paintings would be placed in envelopes regardless of other circumstances. In the event of an evacuation or an emergency we prepared a "crash cart" with all our necessary supplies. The cart stayed in the gallery in a corner work area within the perimeter security. Provisions were made by the building manager for emergency back up power and chilled water for the HVAC system.

The protocol also clearly stated that

"the conservator has the right to recommend to the Bridgestone Museum of Art and the Tennessee State Museum to remove paintings at any time until emergency conditions have been properly remedied. Any dispute regarding the removal or reinstallation of the paintings will be handled directly between the directors of Tennessee State Museum and the Bridgestone Museum of Art."

Knowledge that the paintings could require removal from the walls provided an impetus for all concerned to correct and maintain the proper climate.

The protocol was first adopted in draft form before Mr. Tanaka and Mr. Kaizuka returned to Japan on October 31, and was later modified on December 23. The exhibition was closed on January 20.

As defined in the protocol, my job was to advocate for the collection's safety and security and to work to stabilize the climate. To do this, I went to the Museum every day to survey the environment and care of the collection. Once a week I held a meeting with building, state and museum representatives to sustain progress in stabilizing the gallery climate. At the end of each day I sent a daily report to Japan by facsimile. These reports were helpful in maintaining our work and insuring the accountability of all concerned. Once a week I added copies of each chart from the recording hygrothermographs and a condition report by painting conservators Cynthia Stow or Dee Minault. Over the four month course of the exhibition I averaged two hours of work a day.

THE CLIMATE

In Tokyo, the Bridgestone Museum of Art has a relative humidity between 55-60%. In preparation for the trip to Nashville the collection was acclimatized to 55%. The Museum was very clear in its desire to have the paintings in a constant relative humidity of $55\% \pm 2.5\%$ over 24 hours. To monitor the climatic conditions during transit and exhibition, Mr. Tanaka installed data collectors on the back of Picasso's "Saltimbanque Seated", and Monet's "Water Lillies" while they were inside the crates. To monitor the conditions in the gallery I installed three recording hygrothermographs calibrated with a Bendix psychron. The Bendix psychron was identified as the best calibration tool because it consistently matched Mr. Tanaka's Isuzu computerized monitoring equipment.

The climate in Nashville from October to January is variable. We anticipated gradually lowering temperatures, highly fluctuating relative humidities, weeks of rain and a few arctic blasts.

The Tennessee State Museum is located in the lower levels of the James K. Polk State office Building and Cultural Arts Complex. As illustrated in Figure 1., the building has an office tower which rises above three performance theaters and other facilities. The Museum is located in portions of the two lower levels.

The Museum HVAC system is a variable air volume system which uses chilled water and steam. Steam is also used for humidification. The system was designed to use 14% make up air from the outside

provided through dampers into the system. There was general agreement that climatic alterations must be accomplished through the ducts rather than taking localized measures with portable equipment. This was done to avoid isolated micro-climates around the paintings and to accommodate the dynamics of the air flow into the building and the the 25 foot ceiling heights of each gallery.

Controlling the environment in the Museum gallery was a particularly challenging project for several reasons.

1. The Museum was designed to be seen through large openings from one floor level to another in the lobby spaces of the building and theaters. This creates large open pathways for air to come directly from the street into the *Masterworks* gallery;

2. There was no direct means to monitor the climate in the gallery at the DELTA room, the central computer station for all HVAC equipment;

3. The HVAC equipment did not have adequate humidification capabilities or sensitive control units;

4. The *Masterworks* gallery is located in the corner of a larger HVAC zone. There are two zones on that level, and there are no physical separations between zones.

5. The exhibition proved to be very popular. There were approximately 200 people in a 3,600 sq. foot gallery at any given time over a period of 14 weeks. In the end, 181,000 people saw the exhibition.

Figure 2, shows how outside air enters the gallery. The gallery is two levels below the closest entrance to the building. Air follows the arrows as it enters the lobby and continues to fall down through the "overlooks" (the smallest of which is 31 x 31 feet) down the staircases until it lands in the *Masterworks* gallery.

The week before the exhibition opening a cold front came through Nashville and the relative humidity in the gallery dropped to 37%. This was the first indication that the HVAC system could not sustain the environmental standards of the exhibition which was to last for fourteen more weeks of highly variable weather conditions. To achieve the needed environmental standards for the collection the exhibition area was isolated into a single micro-environment, the perimeter areas were used as buffer zones and all means to prevent infiltration of outside air were employed.

The following steps were taken in this order:

The week before the exhibition -

The outside dampers to the HVAC system were closed to eliminate the use of cold, dry outside make-up air in the HVAC system.

The relative humidity in the building lobby was increased to 55%. This was done to create a buffer envelop around the museum and gallery.

The temperature in the gallery was decreased to 70 degrees F and all the terminals in the ducts were opened to transform the HVAC system from a variable air volume to a constant air volume system. This allowed more air and consequently more moisture to be driven into the gallery to increase the relative humidity.

Three recording hygrothermographs were installed at the front, middle and end of the route through the painting exhibition. The units were installed on the wall at painting level and calibrated for four days until the Isuzu and Bendix psychron's data matched.

A humidifier was relocated into the duct servicing the gallery. This addition brought the number of humidifiers in the ducts to a total of two.

Three humidity transmitters and a temperature transmitter were installed near the recording equipment in the gallery. The data from the three transmitters were averaged in an accumulator. The averaged relative humidity signals and temperature signals were then sent to a new controller. The controller informed the HVAC system of any needed changes in the climate.

A high pressure selector system and sequencing accumulator were installed to allow the gallery humidity controller to override the humidistat in low relative humidity conditions.

Temperature and relative humidity alarms were added to the system. The low setting for relative humidity was 52.5% and the high setting 57%. The low setting for temperature was 70 F and the

high 77F. These settings were consistent with the wishes of the Bridgestone Museum and were also allowed us lead time to solve problems.

During the first week of the exhibition

A second cold front came through Nashville and the relative humidity in the gallery dropped 5% in thirty minutes in the gallery.

A row of bag filters was removed from the HVAC system to increase the air flow by 25%. Increasing the amount of air increased the amount of moisture that entering the gallery.

All outside door closers were adjusted to close as quickly as possible to reduce any infiltration of outside air.

A third humidifier was installed to increase the capability of the system. It was placed in the duct servicing the visitor waiting area outside the exhibit to bolster the perimeter climate area around the exhibition.

The pressure in the building lobby area was reversed. All exhaust fans were shut down in the lobby and adjacent areas thus reversing the air from a negative pressure to a positive pressure at the door. This caused the interior air to go outside causing a substantial reduction of outside air infiltration. This was exciting. No one to our knowledge ever had tried to reverse the pressure in a building one city block square.

Procedures were written to inform the guards how to monitor the climate. The data from the accumulator was transported to the Delta room for 24 hour surveillance. Guards stationed in the gallery 24 hours a day recorded hourly reading from the recording equipment. If the reading fell outside the permissible limits, the guards were to check the accumulator in the mechanical room and contact the Delta room immediately.

Figure 3 demonstrates how the air infiltration was reduced. The modification are shown here in black.

During the first week of the exhibition:

The openings at the base of the stairwell were closed with plywood sealed in place. This restricted outside air from falling through the openings directly into the gallery level.

The doors to the escalator stairwell were closed, again preventing the easy passage of air.

The freight elevator and loading dock use procedures were changed. The elevator opens both onto the dock and into the Masterworks gallery. The elevator was sealed at the gallery level to prevent the cold, dry air from dropping down from the loading dock into the gallery. Procedures were changed to prevent the dock door from being open when the elevator door was open to prevent outside air infiltration.

During the second week of the exhibition

A plastic wall was installed between the ceiling and the top of the *Masterworks* gallery perimeter exhibit wall to reduce infiltration of outside air.

During the third week

We thought we were out of the woods when the mechanical engineer informed us that the system could not sustain 55% if the outside air dropped below 20 F. This was a potential problem. During December, 1989, low temperatures dropped to ten degrees below zero for several days. This was unusual for Tennessee but we could not ignore the possibility of it happening again. Also, the tall buildings downtown create wind tunnels which increased the wind chill.

During the sixth week

The forecast indicated that the temperature would drop to 10 F. Ten degrees below what the engineer reported the HVAC could handle.

Therefore, when the temperature dropped to 15 degrees F, and the relative humidity in the gallery dropped to 53% over twenty

minutes, plastic was installed in the window openings in the escalator stairwell to the gallery level to prevent air flow. Three days after this wall was installed condensation appeared on the ceiling above the stairwell. The corner of the plastic was peeled back to allow controlled air flow. The condensation disappeared and the humidity level in the gallery stabilized.

No further modifications were made to the the building after this point. However, adjustments to the controller were made to fine tune how the system operated. At no time, during the exhibition, did the environment leave the contractual limits for more than eight hours. The charts from the recording hygrothermographs showed our progress. The chart lines remained largely flat and with the 2% variation we were permitted.

Our results in stabilizing the climate were very satisfying. At no time did the environment ever leave the appropriate range. To achieve the desired results we buffered an outer envelope to the gallery and physically created a micro-environment within the gallery and restricted air infiltration as much as possible. All the equipment and labor costs to modify the building and gallery were under \$5,000. The alterations to the climate had a negligible effect on the climate in the other gallery areas. Although the contract amendment was not signed during the exhibition, the protocol for emergencies directed my authority.

I want to thank Governor Ned Ray McWherter for his direct support of the exhibit, Mr. Yasuo Kamon, Director of the Bridgestone Museum of Art and Mrs. Lois Ezzell, Director of The Tennessee State Museum, for asking me to participate in this project. To Chiaki Tanaka, Conservator and Tsuyoshi Kaizuka, Assistant Curator, from the Bridgestone Museum of Art for their support and determination.

I also want to give my special thanks to Hunter Allen, consulting mechanical engineer for Johnson controls, who services the HVAC equipment at the Tennessee State Museum. To Bill Griffith, special representative of the State of Tennessee for the building who approved our expenses on this project and Mr. Ernest Dearmen, building manager who pointed his staff in any direction the project required. To Bob Pennington and Peg Schneider from the Tennessee State Museum who helped in monitoring the gallery. To Barbara Heller and Leon Stodulski at the Detroit Institute of Art for their prompt and thorough analysis of water and paint samples. And to all

of them and to my friend and colleague Steven Weintraub, who shipped our equipment overnight. A special thanks for all their assistance and constant focus of the care of the paintings.

Figure 1
JAMES K. POLK STATE OFFICE BUILDING AND CULTURAL ARTS COMPLEX

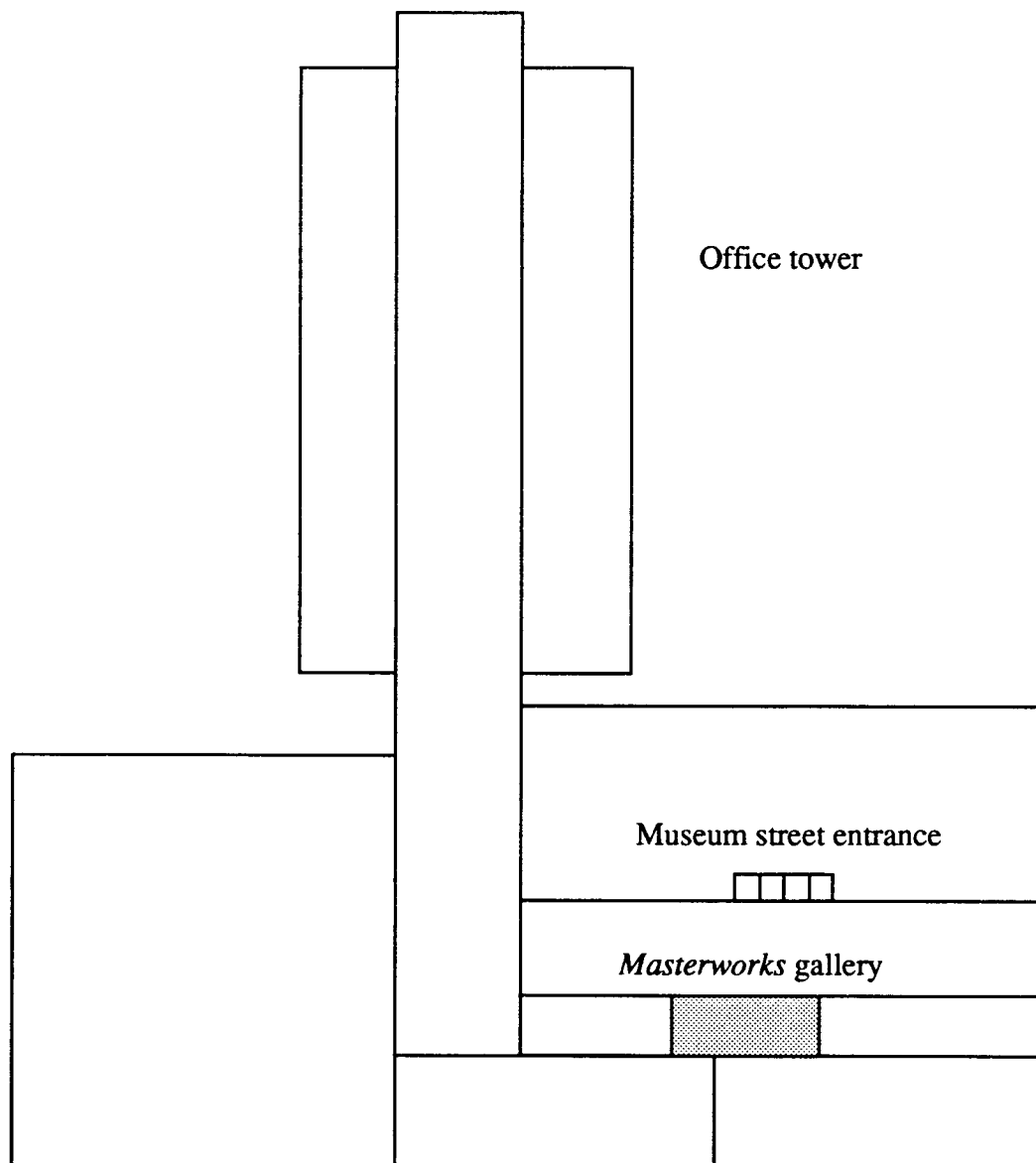


Figure 2

PATTERN OF OUTSIDE AIR FLOW INTO THE *MASTERWORKS* GALLERY

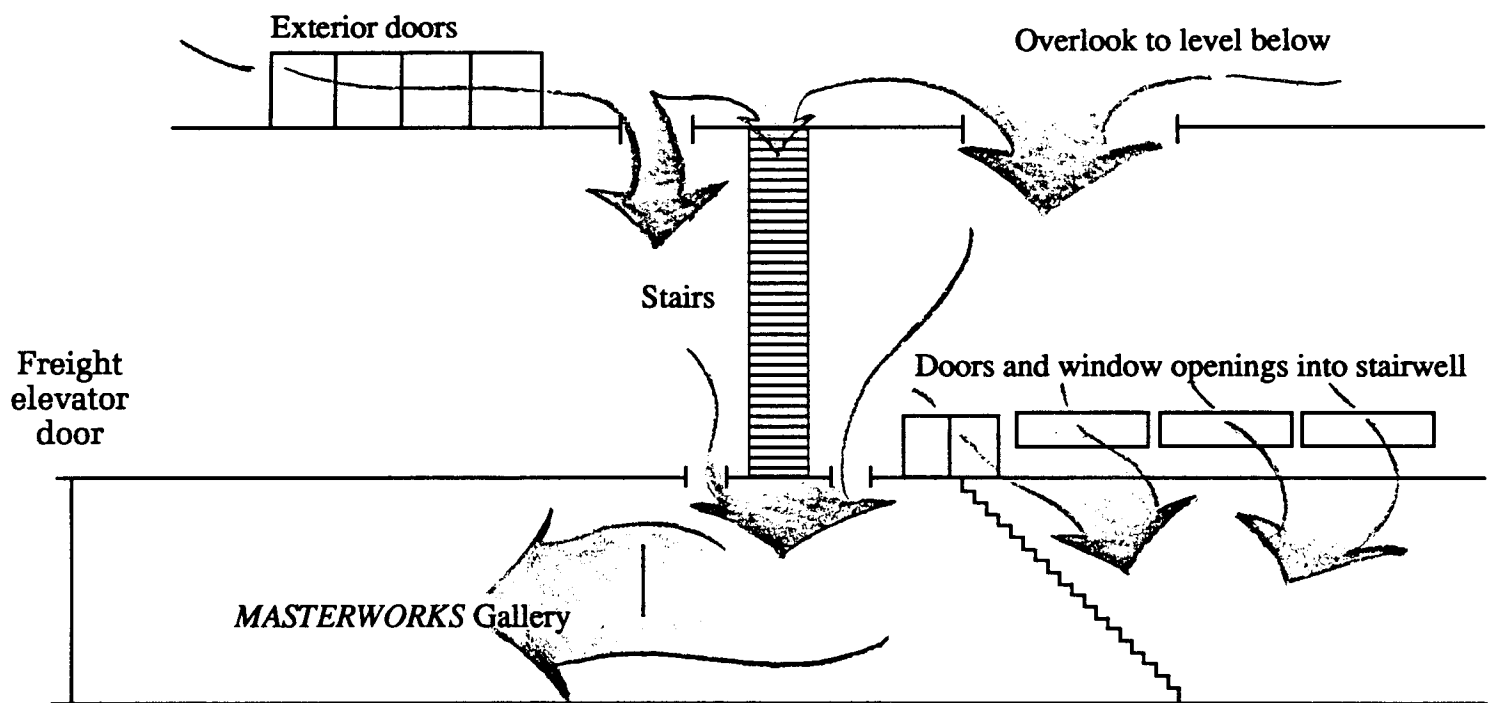
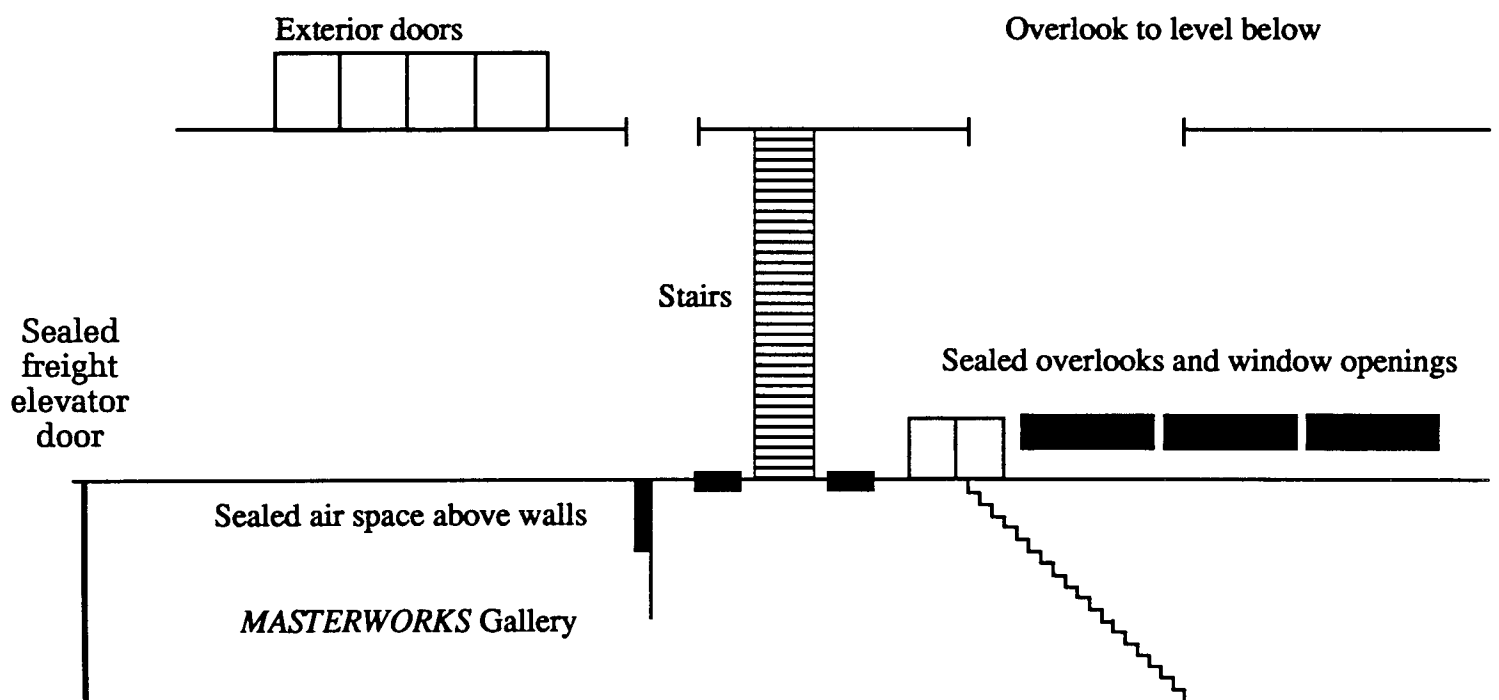


Figure 3

MODIFICATION TO REDUCE INVASION OF OUTSIDE AIR INTO THE *MASTERWORKS* GALLERY



AIRTIGHT, HUMIDITY STABILIZED DISPLAY CASES:
The Practical Design and Fabrication of
Sealed Exhibit Cases

by Toby J. Raphael

Abstract

Humidity "stabilized" or "buffered" case designs are a relatively simple but useful technology which has been under utilized. This type of exhibit microclimate has not been widely adopted by small museums and historical sites where overall humidity control is often unachievable. Conservators at the National Park Service have developed specially designed exhibit cases in a program aimed at upgrading the permanent exhibits in National Parks across the country. This paper outlines the conservation parameters for fabricating sealed cases and identifies a number of alternative designs for achieving passive humidity control.

Introduction

This year marks the 75th Anniversary of the National Park Service (NPS) and for much of this period it appears that "exhibit case design" has contributed unnecessarily to the deterioration of our collections. An effort is now being made to improve the long-term preservation of our exhibit objects by paying particular attention to exhibition design and construction to ensure the utilization of the highest standards possible and incorporation the most practical and current conservation technology. This effort, in conjunction with the increased involvement of conservators, have significantly lengthened the time we feel we can safely display our tremendously varied collections.

The role of the NPS is to preserve and protect both the nation's "natural" and "cultural" resources which are entrusted to its care. One of its biggest challenges has been to create an inviting and stimulating exhibition environment that does not endanger the collections on display. A systematic program for collections care has been developed by NPS curators and over the past five years conservators at the central exhibits facility in Harpers Ferry have experimented with numerous designs for passive humidity control in "low-maintenance" display cases.

TOBY RAPHAEL WORKS FOR THE NATIONAL PARK SERVICE AT ITS CENTRAL MUSEUM
FACILITY: HARPERS FERRY CENTER, DIVISION OF CONSERVATION,
HARPERS FERRY, WEST VIRGINIA 25425

We recommend the use of humidity "buffered" or "stabilized" cases to our exhibit designers when display materials are humidity sensitive but can tolerate a slight range of relative humidity fluctuation. The principle benefits of these case designs are: 1) that they have proven to be effective in reducing the risk of unnecessary damage and deterioration to these collections, and 2) that they are an extremely cost efficient approach to climate control.

We have found that these cases can help preserve display materials in museums and at historical sites where overall climate control is impractical, enormously expensive or destructive to the building site. Their use can also allow for the exhibition of sensitive objects in places where curatorial and conservational expertise are limited or unavailable.

The annual recording of Rh at a wide variety of our exhibit sites (including those without any humidity control) has shown that in most open exhibit spaces the range of Rh is unacceptable for humidity sensitive materials, however, the "average" of Rh readings falls within the acceptable range of 40 to 60%. In these instances buffered cases can usually function very effectively. We have found some climatic exceptions, however, which generally include our sites in extremely arid and tropical climate areas.

Our experience has shown us that the effectiveness and performance of these cases depends on the cooperation and collaboration between designers, curators, conservators and exhibit fabricators. When this type of case design is selected, exhibit planners must concern themselves with the total exhibit environment created through the interplay of the exhibit building's environmental conditions, the case design and fabrication materials used, and the curatorial staff.

A Simple And Practical Solution For Some Exhibits

Tim Padfield said in 1967 that a properly designed display case is probably the greatest single aid to conservation. Over the past decade numerous outstanding ideas and technological approaches have been presented on the subject of microclimates; however, too few institutions and conservators alike, have put into practice the knowledge that our field has already developed and proven useful. Amazingly few such case designs have been developed, tested and adapted for common museum usage.

We have developed our exhibit program around the premise that practical, "low-tech" solutions are available to solve most of our museums' conservation needs. The criteria of reliability, simplicity and practicality have therefore been key objectives in our search for suitable case designs. From a conservation perspective, we are finding that our most successful exhibits maintain a "simplicity" of design while meeting our established conservation standards.

To insure successful performance, practical and reliable engineering is essential. When appropriately engineered and constructed, airtight cases offer nearly total protection from insect entry, dust and soil

accumulation, vandalism and handling, as well as damaging climatic conditions.

Special Museum Circumstances And Airtight Cases

Humidity buffered or stabilized case designs are a relatively simple technology which is particularly useful for museums which must rely on preventive conservation measures because of budgetary and personnel constraints.

Museums which were initially built for the purpose of exhibition and major museums in urban / metropolitan areas have a reasonably good chance of achieving overall climate control in their display galleries. The museums and historical settings with which we routinely deal in the NPS, however, are often in rural areas or unconventional environments and generally have no realistic means for controlling humidity and other mechanisms of deterioration. The special exhibit circumstances we find are much like those of many smaller museums and include the following:

- Inadequate control of relative humidity (Rh) within exhibit halls: both unacceptable levels and rates of fluctuation.
- Temperature swings which occasionally fall outside of recommended parameters due to lighting and seasonal change.
- Dust and airborne soil entry present a serious maintenance and conservation challenge.
- Insect entry is difficult, if not impossible, to control: due to geography, visitor traffic and building configuration.
- Few trained curatorial staff are on site and the extent and quality of exhibit maintenance may vary tremendously.
- Exhibits are usually considered permanent installations: the site may request a new exhibit every 10 to 20 years.

When faced with these circumstances at NPS sites we find we select closed case designs more and more frequently. Airtight cases have proven most suitable not only because they make excellent microenvironments - air exchange is greatly reduced and relative humidity can be effectively stabilized with less moisture absorber for longer periods of time - but because of their added protective features regarding insects, pollutants and temperature swings.

Special Design Considerations

We have identified four special design and fabrication considerations which play a very important role when sealed exhibit cases are being designed and built. The following points should be considered when these displays are specified:

Inert Materials

Particular attention must be paid to assure that sealed cases employ materials that are inert and of high quality. Low quality fabrication materials can be hazardous when exposed within case interiors because

they can damage objects by subjecting them to volatile substances which build up to dangerous levels within sealed cases.

Isolation of Harmful Materials

Potentially hazardous materials which are exposed to the case interior can be isolated to some degree with barrier coatings or certain laminate materials.

Reducing Air Leakage

Sealed cases need to employ design features and fabrication techniques which minimize the air exchange between the case and the general exhibit space. Tolerances between joints should be more restrictive than normally required for unsealed exhibit casework. All openings including glazed openings and doors require sealing with gasketry or caulk.

Heat From Exhibit Lighting

Sealed cases are particularly susceptible to overheating as a result of inappropriate exhibit lighting. Case interiors can experience temperature rise due to convection and infrared radiation which is made more dramatic because of the "green house" effect. Lighting fixtures and bulbs must be carefully evaluated to ensure their effect on the case's atmosphere is not destabilizing. Exterior, ceiling lighting does not present the threat that attached, above case lighting does. Double glazing and infrared reflecting glass can be used, for example, to isolate from the display area lighting systems which are attached to cases.

Humidity Control And Airtight Cases

The relative humidity of the air in a traditional, non-absorbent display case will approximately follow the average, daily Rh of the exhibit room. When cases are made airtight and a moisture absorbing material is added, daily humidity fluctuation is eliminated and weekly and even monthly fluctuations are drastically reduced. It is possible to stabilize yearly Rh levels to plus or minus 5%, even when ambient humidity is uncontrolled.

In our experience it is rarely necessary to consider the use of anything other than the passive approach to humidity control (as opposed to a mechanical method, such as the use of a micro climate generator). Our cases are not engineered to "fix" relative humidity but rather to stabilize or buffer the interior environment from the more rapid changes occurring outside of the enclosure. The humidity levels in these cases are, by design, self regulating between seasons and will ultimately reflect the yearly average of the exhibit room at large. We find we can maintain an annual interior range of 40 - 60% Rh, with the rate of seasonal change-over not exceeding 5% Rh per month.

Airtight cases do not constitute hermetically sealed enclosures; however, their design and fabrication do require that the structures be as airtight as possible, incorporating gasketry and sealant caulk to greatly reduce the rate of air leakage. Technical evaluation procedures are now available to pinpoint case leakage and measure the rate of air

exchange in a given exhibit case. This technology is steadily becoming more affordable and will undoubtedly be widely used in the future.

The principal means by which Rh escapes from these enclosures is through diffusion and permeation of the exhibit case materials. Additional forces at work are convection, thermal pumping and barometric pressure change. Although diffusion is a serious concern when trying to maintain a constant Rh it occurs very slowly and acrylic glazing as well as glass is acceptable for use in humidity controlled case design. Convection, on the other hand, works to drive vast quantities of air out one small gap or hole and in another, taking moisture with it. CCI Conservator Stefan Michalski has explained that the effective stabilization of RH in sealed exhibit cases therefore depends on the successful limitation of convection losses and this can be accomplished by ensuring that:

- 1) all gaps are sealed effectively with gasketry or caulk and,
- 2) whenever possible, to reduce convection, lateral case entry design should be used (such as five sided acrylic vitrines).

Moisture Absorbers

Airtight display units should be designed to incorporate a humidity "buffer" or moisture absorbing and releasing materials. The term "buffer" has been used to denote any material which resists or helps to buffer a change in the Rh of the air surrounding it, whether this change is caused by a leakage of air at a different RH or by a change in temperature. If the Rh of the air falls, then the buffer, in order to keep in equilibrium with the air, will give out some moisture. This moisture will cause the Rh to rise thus counteracting the change, and vice versa. So much more water is locked up in moisture absorbent materials than in air that the short-term effect of the buffer is actually to compensate for a change in Rh caused by a temperature change or air infiltration.

All organic materials have a moisture absorbing quality, however certain substances have the capacity to absorb more moisture or to pick it up faster. Within airtight cases we have successfully used buffers in the form of natural products (such as cotton batting, wood and paper cellulose fiber) or man-made products (such as regular density of hybrid silica gels).

Within each display case a maintenance chamber should be included to contain the quantity of the absorber which is calculated to protect the case throughout the year. The quantity of buffer is substantially less than that which is recommended for leaky cases, and as a rule, should not require maintenance, under most circumstances. Only under emergency conditions would a small amount of moist or dry silica gel need to be added to "boost" the permanent buffer. We frequently have added a small maintenance door (ie. 4' X 4") for this purpose.

The buffer is usually located under the display deck or plinth and air circulation is encouraged by allowing for 15 to 20% communication through or around this platform.

Silica gel products have proven the most reliable, however, they differ in their effectiveness within varying ranges of humidity. Certain, new hybrid gel compounds have been shown to absorb and release moisture more efficiently within the range useful for most of our museums. Artsorb and Arten Gels are appropriate commercial products which are available from conservation suppliers. In most instances, we use 1/3 lb. of these gels per cubic foot, or roughly 9 lbs. per cubic yard.

Silica gel used within airtight cases should be contained in a standardized enclosure or container for quantity control and maintenance purposes. We have used inert plastic tiles, tubes or fabric bags and impregnated paper and foam products which are commercially available. Economical containers can also be fabricated to suit the needs of an exhibit case. Standard sized, pleated nylon bags and custom panels are made in-house and have proven to be the most successful and cost effective.

Exhibit Case Gasketry and Sealant Caulk

Gaskets serve to control interior case humidity and temperature as well as the entry of unwanted pests, airborne soils and pollutants. Gasket characteristics, design and location must, therefore, be carefully selected since gasketry plays a fundamental role in sealed exhibit cases.

A variety of gasket designs and elastomer materials are commercially available, however, not all are appropriate for use in exhibit cases. From our experience we have formulated the following recommendations which are aimed at insuring both successful performance and the selection of safe gasket materials:

1. Appropriate gasket materials should be employed to seal all doors, removable panels and exhibit case glazing. Extruded or sheet elastomers are available.
2. Only high quality and chemically inert gasketry materials should be selected, thus assuring that the gasket itself will, in no way, contaminate the interior exhibit space.
3. Gasket design should be suitable for its particular application and its short and long range performance thoroughly considered i.e. a routed channel can be employed, whenever possible, to allow for additional compression space.
4. Ideally, proposed gaskets should be tested for chemical stability and effectiveness of design application. When testing is not possible, product data and specifications should be reviewed by an exhibitions conservator. We have found the material cellular silicone sponge (dimethyl-poly-siloxane) to meet all of our criteria.

To further assure that display cases are as tightly sealed as possible it is an acceptable practice to finish interior or exterior seams and joints with caulking. Acrylic and silicone caulk can be used both effectively and safely, however, both require a cure time of several weeks before object installation can occur. Certain caulking products are neutral curing and do not emit acetic acid during their curing, such as the caulking product manufactured by General Electric #2501.

Selection of Construction Materials

To ensure the long-term preservation of objects exhibited in sealed cases, we have found that all materials used within the exhibit enclosure must be carefully selected.

Unsafe or low quality materials can encourage both chemical and biological damage of objects when these materials are enclosed with objects within an exhibit enclosure. For this reason it is very important that case materials be selected on the basis of their inertness; i.e. substances that will not present a hazard to the exposed objects. Ideally, all unknown fabrication materials should be tested to identify the presence of organic acids or other harmful components. Careful consideration, therefore, must not only be given to the selection of the case's structural materials but the adhesives, paints, finishes and laminate materials used as well.

From a conservation perspective, it is preferable to construct exhibit case structures from non-reactive materials such as metals since they are dimensionally stable and are not known to emit any harmful vapors. Aluminum, steel, and brass have been successfully incorporated into a variety of case designs. For reasons of cost and aesthetics these materials are often excluded as fabrication materials, and traditionally, more problematic materials, such as wood and wood products, have been the construction materials most commonly used.

We try to follow four basic guidelines regarding fabrication materials:

1. All construction materials which comprise a part of the "interior" case environment should be free of acid or harmful volatile chemicals.
2. New and previously untested materials should be tested to identify the presence of organic acids or other harmful components. Testing services are available commercially and our conservation laboratories can perform some less complex testing.
3. Before objects are installed within an enclosed case all surfaces and construction materials must be absolutely dry and fully cured: paints, adhesives and caulks generally require a minimum of three weeks. Objects should not be placed immediately into newly constructed cases.

4. Only inert materials should be in direct contact with display objects. Unknown materials, reactive materials, dyed, painted or abrasive surfaces must be isolated from contact with artifacts by an appropriate, conservation-approved isolating layer (i.e., linen, cotton or polyester fabric, polyester or polyethylene film, acid-free paper or paper boards).

Use of Wood Products For Case Construction:

From a conservation perspective, wood and wood products are not ideal materials for exhibit case construction, particularly in the instances of sealed cases. Wood emits corrosive vapors (acids and compounds) which can be harmful to many objects and certain precautions must be enforced if wood is used with exhibit cases. Free acetic and formic acid are contained in all wooden materials and more acid is generated over time by the hydrolysis of the acetyl groups of both soft and hard woods. Elevated temperatures and high humidity increase dramatically the release of gaseous vapors.

We try to substitute non-wood products whenever possible and select safe and chemically inert materials whose composition and characteristics are known. Excellent wood substitutes includes: acrylic or polycarbonate sheeting and extruded paneling, such as Plexiglas or Lexan thermoclear panels; aluminum honeycomb paneling, such as Hexcel honeycomb sandwich; and paper honeycomb board, such as Tycore paneling.

In constructing cases, we make an effort to use the least corrosive wood products possible. In a study of the corrosive potential of wood toward metal (lead), Honduran mahogany was found to be the least corrosive because of its inherent lower acid content and low permeability characteristics. Try to limit woods used to; (soft woods) poplar, basswood, and spruce; (hardwoods) mahogany, walnut, birch and balsa wood.

Whenever possible, we avoid the use of plywood and particleboard. If plywood must be used in exhibit case construction, we specify:

- 1) the highest grade (Type 1, Grade AA or BB exterior plywood) with phenol-formaldehyde adhesive, or,
- 2) interior grade plywood with hard wood veneer using phenolformaldehyde adhesive (check with major lumber suppliers or contact the Hardwood Plywood Manufacturer's Association), or,
- 3) particle Board using phenol-formaldehyde adhesives.

Special protective coatings or laminates must be used to isolate all raw wood and wood product surfaces and edges that are exposed to the interior of exhibit cases. These materials should be sealed to reduce the outgassing of harmful, volatile substances. Remember that only certain laminates and sealants provide an effective barrier.

We use a variety of products which we have evaluated to isolate wood products. These laminates and sealants fall into the following categories:

- metal foil (such as aluminum)
- metalized plastic film (such as aluminized mylar)
- high pressure laminates (such as Formica, Micarta)
- epoxy (certain 100% solid, two part coatings)
- moisture cured polyurethane

Use of Adhesives In Case Construction

A wide variety of glues and adhesive systems have commonly been used in the assembly of exhibit cases. We have found that most adhesives emit vapors during their drying or setting phase and many continue to outgas throughout their serviceable lifetime. Research has shown that some of the most damaging construction adhesives fall into the categories of "contact" and "pressure sensitive" adhesives. New and complex formulations are available on the adhesives market at an increasing rate and many of these materials have the potential to harm sensitive display materials. In our experience careful scrutiny of these products is necessary in order to maintain a protective microenvironment.

We try to follow the following guidelines regarding adhesives:

1. Use mechanical fastening and avoid the use of adhesives altogether, whenever possible.
2. Depending on the placement of an adhesive it may or may not be exposed to the interior display environment. Utilize the design of exhibit case and construction techniques to inhibit the possible entry of volatile adhesive components. Utilize acceptable laminates and caulking of joints as effective barriers.
3. Use known adhesive systems which have a track record and include acceptable chemical components, i.e. acrylic resins, polyvinyl acetate and silicone adhesives.
4. Allow sufficient time for the curing and setting of adhesives before display materials are enclosed in the exhibit case. A minimum period of three weeks is recommended during which case doors should be open.

Use of Decorative Fabrics, Case Liners and Paints

We use a wide range of fabrics to line exhibit case interiors to achieve a variety of decorative objectives. It is extremely important, however, to systematically review these materials and their installation techniques in order to avoid introducing a source of potential damage to the display objects. Textiles are frequently used to line the interiors of sealed display cases yet only certain textiles are considered safe for this function. Both the fiber composition and dye used must be

examined to reduce the risk of contaminating the exhibit environment or risking dye transfer to objects. Wool fabrics (including felts containing wool), for example, should not be used because of the fabric's emission of volatile sulfur compounds. Pure cotton, linen, silk and even polyester fabrics are suitable. Fabrics containing other fibers should be tested as should dyed textiles to identify dye fastness in water.

Paint systems that our exhibit designers select for use within display cases require similar care in selection. Alkyd or oil based paints are a poor choice since they are known to outgas for long periods of time. Acrylic and acrylic latex paints have shown to be the most compatible paint system for internal exhibit use. The longer the curing time the better.

We try to follow three recommendations regarding case interiors:

1. Select safe fabrics for use within exhibit cases and prewash and dry them before installation to remove sizes and finishes and to preshrink the fabrics.
2. Attach liners by mechanical means whenever possible. It is recommended that adhesives not be used. Double sided adhesive tapes are not considered permanent yet the archival quality tapes can be useful in this function. Rust proof staples and tacks are also available for the attachment of fabric liners, while sewing is considered the safest option.
3. Review the composition of commercial wall paints and use only conservation-approved paints; allow sufficient cure time before installing objects.

SIMPLIFIED PROCEDURES FOR RECONDITIONING SILICA GEL

by Steven Weintraub

INTRODUCTION

Control of relative humidity within an exhibition case through the use of silica gel is a technique that has been practiced within the museum community for approximately 30 years. In spite of the proven effectiveness of this system of humidity control, its use is limited, because there is a perceived difficulty involved in maintaining and reconditioning a silica gel system. In reality, reconditioning can be performed simply and economically. A simple reconditioning method is the subject of this paper.

TRADITIONAL CONDITIONING TECHNIQUES

Silica gel is conditioned outside the case to a desired humidity. Typically, the gel is placed in a space or environmental chamber conditioned to the proper RH. Alternatively, the gel is placed in a high RH environment and checked periodically until it has adsorbed the proper amount of water. This process can take a significant amount of time. A single layer of dry silica gel may require two days or more to equilibrate with a 50% RH environment. Each additional layer significantly slows the rate of conditioning. The process can be accelerated both by using a forced air flow across the silica gel bed and by maximizing gel surface area and minimizing depth of gel. Direct addition of water in its liquid phase is not recommended since the high heat of adsorption breaks up the silica gel bead.

Eventually, the conditioned gel may require reconditioning as a result of gaining or losing moisture through case leakage. Traditionally, the total amount of silica gel is removed from the case and reconditioned using the same method described above for dry silica gel. This technique is extremely inconvenient and labor intensive. The case must be designed so that all the silica gel can be removed. A special climate controlled space is required to condition the gel.

Art Preservation Services
539 E. 81st St.
New York, N.Y. 10028

THE IN-SITU METHOD FOR CONDITIONING SILICA GEL

There is a relatively simple method for reconditioning silica gel without removing it from the exhibition case. Moisture content is adjusted by either adding or removing water. The relationship of moisture content and relative humidity is well known for the standard types of silica gel used for humidity control in museums. This information is used to calculate the amount of moisture to be added or subtracted in order to change the silica gel's equilibrium point from one level of RH to another.

In order to demonstrate the concept, the following examples are used in order to adjust relative humidity in a sealed case. The actual Moisture Content/Relative Humidity (MC/RH) ratios used in the example calculations are simplified approximations of values for a "typical" silica gel. Actual ratios should be determined by reference to the MC/RH curves for a specific type of silica gel as supplied by the manufacturer.

MOISTURE ADDITION - Assume that the case is at 40% RH and the goal is to raise the case RH to 50% -

1) Determine the moisture content of silica gel at 40% and at 50% RH. Assume that at 40% RH the silica gel contains 25 grams of water per 100 grams of silica gel by dry weight, and at 50% RH, the gel contains 30 grams of water per 100 grams of silica gel.

40% RH = 25 grams water/ 100 grams dry silica gel
50% RH = 30 grams water/ 100 grams dry silica gel

2) Determine the amount of water necessary to raise the case RH from 40% to 50%. If the silica gel contains 25 grams of water at 40% RH and 30 grams at 50% RH per 100 grams of dry silica gel, it is necessary to add 5 grams of water per 100 grams of dry silica gel to raise the equilibrium moisture content (EMC) of the silica gel from 40% RH to 50% RH. The addition of 5 grams of water per 100 grams of silica gel is the equivalent of adding 5% by weight of water to silica gel.

$30\% \text{ MC (EMC at 50\% RH)} - 25\% \text{ MC (EMC at 40\% RH)} = 5\% \text{ MC.}$

3) Calculate the total amount of water that must be added to a case by multiplying the amount of silica gel in the case by the percent of water that must be added. If the case contains 10 kilograms of silica gel (by dry weight), 5% of 10 kilograms is 500 grams. Therefore, it is necessary to add 500 grams of water to the case.

$10,000 \text{ grams silica gel} \times 5\% \text{ MC} = 500 \text{ grams water to be added.}$

MOISTURE SUBTRACTION - Assume that the case is at 50% RH and the goal is to reduce the case to 40% RH -

Repeat steps 1) through 3) above, but in this instance, the goal is to remove 500 grams of water. In order to remove water, dry silica gel is added to the case. It is necessary to determine how much dry gel to add such that the entire bulk of gel, including the new addition, comes into equilibrium with the new RH set point of 40%.

Each 100 grams of dry silica gel can adsorb 25 grams of moisture (25% EMC) in order to be in equilibrium at 40% RH. Dividing the total 500 grams of water to be removed by 25% EMC equals 20. 20 represents the number of units (100 grams) of new dry gel that must be added to the case. Therefore, 20 x 100 grams of silica gel equals 2,000 grams of dry silica gel that must be added to the case.

500 grams water/ 25% (EMC at 40% RH) = 20 units of 100 grams of dry gel required.
20 x 100 grams dry silica gel = 2,000 grams dry silica gel to be added.

Therefore, according to the first example, 500 grams of water must be added to the case to bring 10 kilograms of silica gel up from 40% to 50% RH. Two thousand grams of dry silica gel must be added to bring 10 kilograms of silica gel down from 50% to 40% RH. By adding the appropriate amount of water or dry silica gel, the original load of 10 kilograms of silica gel never requires removal, and the entire reconditioning process takes place directly in the exhibition case.

APPLICATION NOTES

1) The bulk conditioning silica gel should be properly distributed within the case. Since the reactivity of the silica gel slows down significantly with depth, it is best to ensure that the silica gel is not deeper than 3/4 to 1 inch. Since the bulk density of most silica gels averages 45 pounds/cubic foot, approximately one square foot of silica gel should contain about 2 1/2 to 3 1/2 pounds of silica gel.

2) If the silica gel is properly distributed, the RH within the case should be dominated by the surface of all organic materials and the top layer of silica gel within the case. As the reconditioning water evaporates or the dry gel adsorbs excess moisture, the case RH will not change abruptly because of the dominating presence of these other buffering materials. In fact, the gradual reconditioning that occurs in-situ is safer than the quick adjustment that occurs when the bulk gel is removed, reconditioned externally and then added in mass to the case.

- 3) The process of reconditioning can be accelerated or slowed down by controlling the surface area of the reconditioning water or dry silica gel.
- 4) Silica gel is a moisture buffer which is used to slow down the RH exchange between the case and the room and has a finite buffering capacity. At a certain point, if the case has an excessively large amount of leakage, no silica gel system will be able to stabilize case RH for any reasonable length of time. Therefore, the case should be as well sealed as possible.
- 5) If the case has excessive leakage, it is possible to overcompensate by adding excess water or dry gel with an appropriately large surface area. While there is a risk of creating excessive and rapid changes in RH by the uncontrolled addition of dry gel or water, the presence of a large quantity of bulk silica gel will buffer against such extreme shifts in RH.
- 6) The proper amount of bulk conditioning silica gel should be used in an exhibition case. Various formulas have been suggested in the literature. In all instances, these formulas make certain assumptions about case leakage, moisture content/relative humidity ratios, acceptable length of time between periods of reconditioning, etc. Given normal conditions of use for high performance silica gels such as Arten Gel or Art Sorb, 5 to 10 pounds of silica gel per cubic yard provides a reasonable measure of protection. It is better to use the larger quantity of silica gel if very stable conditions are required, or if long periods between condition is preferred, or if there is significant case leakage or a large differential between case and room RH.
- 7) Because of leakage and the presence of other moisture sensitive materials, RH adjustment as calculated above will always tend to undershoot the RH goal, since these factors are not taken into account. There is no harm in undershooting since additional water or dry gel can be added. If, by experience, the case humidity is adjusted only half way, approximately twice the amount can be added subsequently to take these other factors into account.
- 8) Sufficient air exchange should be permitted between the silica gel storage area and the display zone which contains the artifact. Additional research will be necessary to provide specific recommendations on minimally acceptable spacing for such air/RH exchange slots or holes.

MAINTAINING HIGH RELATIVE HUMIDITY WITH ACTIVE AND PASSIVE SYSTEMS IN LARGE EXHIBITION CASES

Arthur Beale

Like many older museums in the United States built at the beginning of this century, the Museum of Fine Arts, Boston has had a difficult time retrofitting its buildings with climate control that meets with current standards for collections care. Even in its West Wing special exhibition galleries designed by I. M. Pei and built in 1981, HVAC mechanicals and control are now out of date and have trouble coping with block buster shows with big crowds at certain seasons of the year. While experience and studies done at the MFA, Boston and elsewhere have clearly shown that new construction with state-of-the-art climate control is often considerably cheaper than renovation of many existing structures and systems, other factors, such as location, often dictate the more costly solution. Because of the astronomical costs associated with these conversions, only about 40% of MFA spaces are truly climate controlled with perhaps another 20% served by some form of air-conditioning.

As a result of this situation, MFA conservators starting with William Young as early as the 1930's have developed both active and passive microclimate systems for both large and small exhibition cases in the museum. Recently in the process of building a new case for a particularly humidity sensitive Egyptian limestone sculpture, we discovered the old case contained a formerly active device built by Young in 1939 to lower relative humidity in a confined space. This "artificial atmosphere" was designed to keep humidity steady and low, at or below 30% RH, by pulling air with a small electric pump through a box full of moisture absorbing calcium chloride. A cylindrical drum in the system served as a miniature "gasometer" designed to equalize atmospheric pressure in the airtight case.¹

The new system designed for this same Egyptian sculpture in 1991 is "passive" in nature as it has no moving parts driven by electricity. The old system was "active" by this definition, but manual in the sense that the electric air pump was not connected to a sensor. Someone had to look at a hygrometer gauge inside the case and flip a switch when the humidity began to get above 30% RH.

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¹ An interesting paper given at the 1988 IIC Congress in Kyoto, Japan, The Conservation of Far Eastern Art, entitled "Conservation and Exhibition of Cultural Property in the Natural Environment in the Far East" by Kenzo Toishi and Masako Koyano, pp 90-94 describes the use of an airbag as a "pressure dissipating" unit to help extend the life of conditioned silica gel in a tightly closed space.

The new system represents the type now widely used throughout the MFA. It also requires monitoring a small hygrometer dial to read relative humidity and then removing and reconditioning the silica gel used inside the case when the relative humidity climbs unacceptably above or below the desired level. Since the main topic of this paper centers on systems for large exhibition cases, I will not go into too much detail about our smaller cases except where the materials and hardware used have applicability to most any size case.

The first design criterion we have for all these cases is that we have access to the silica gel or machinery used to control relative humidity without having to move or disturb the objects housed in the cases. The design assumes that we are aiming to control relative humidity while allowing some temperature variations. The Museum is heated in the winter, but none of the areas where microclimate cases exist are air-conditioned (cooled) in the summer. I mention this because it has become clear to us through our research and experience that while air-cooling for visitor comfort often leads to drastic unacceptable shifts in relative humidity for the collections, active systems such as the Kennedy-Trimnel Relative Humidity Control Module, function more effectively within fairly stable temperature ranges. This will be discussed in greater detail later on in this paper.

Because these are closed spaces, another criterion used in case design is that all construction materials must be as inert as possible or sealed to mitigate against the outgassing of organic acids, formaldehyde and other aldehydes. The seals, achieved with gaskets in passive systems, must be as tight as possible to minimize the frequency of adjustments needed to keep silica gels at the desired performance level. To achieve this degree of tightness in case construction requires careful manufacture, augmented with glued joints and caulking compounds. For cost, speed, and ease of construction, our museum, like most, uses wooden case construction. Although some decorative elements may be constructed of other woods, the basic and interior elements of the majority of our cases are made of M.D.O. (Medium Density Overlay) sign board. This is a fir plywood bonded with type 1 exterior adhesive, phenol-formaldehyde, and faced with kraft paper to form a smooth surface.² The case sections are generally nailed and glued together, preferably with an acrylic emulsion adhesive, and sealed with three coats of Camger moisture-borne polyurethane Polyglaze 1-146 or with Sancure 878. These products

² Although our "Oddy test" experiments have shown this plywood to be one of the safest of the ones we have tested from the point of view of volatile acid emissions, the laboratory at the Walters Art Gallery has not reported good results with this product in their experiments (see "Fixtures at an Exhibition Part I. Wood Product and Sealant Testing" by Donna Strahan in this publication). We plan to conduct more refined experiments in the near future to test the safety of this product. A recent review of our test samples suggests that different results are obtained from both M.D.O. and MedexTM depending on the age of the sample tested. In short, newly manufactured samples of either material seem to outgas products that resulting lead corrosion.

are often cut with water.³ Often latex paints are then used on exterior surfaces as a final finish. Joint sealing or caulking in interior surfaces is done with Dow Corning No. 3145, RTV adhesive/sealant.⁴ This product was chosen because it does not emit acetic acid while curing. A minimum drying time of two to four weeks is allowed for these sealing and caulking products. Where plexiglass vitrines fit into wooden grooves on bases or on the back of silica gel compartment access doors, we generally make our own gaskets out of 1/8" pcf2A black polyethylene foam (VolaraTM Type A)⁵ cut into strips and adhered with 3M 1/2" wide, double sided, self-adhesive tape No. 413 (Part No. 03764).

Other materials that may outgas harmful vapors are fabrics or decorative paint that may be used inside a case. These materials are, therefore, also tested before use, and fabric routinely washed in warm water to remove any excess finish that may emit formaldehyde.

In developing individual case designs, additional criteria applied are to minimize the internal space to be controlled, especially by passive means, and to maximize the areas of air exchange between the silica gel compartment and the enclosed exhibit space. In general our silica gel compartments are made no larger than is necessary to contain and easily remove 3" diameter module canisters or 2" high aluminum trays. The rule of thumb used in our calculations for the amount of silica gel necessary, dependant upon the efficiency of the silica gel, is 5 to 10 kilograms (10 to 20 pounds) per cubic meter of air being conditioned. Alternatively, 150 grams per cubic foot translates into 5.35 kilograms per cubic meter.

In general, we allow air exchange between the silica gel compartment and the exhibit part of the case in one of three ways; 1 1/2" to 2" holes spaced every 6" to 9" on center drilled in decks and covered with fabric, three visible 1/2" wide parallel

³ Camger Polyglaze 1-146 is available from Camger Chemical Co., 364 Main Street, Norfolk, MA 02056, tel. 508/528-5287. This product was produced for us using Sancure number 878 as a base material as a result of research conducted by Pamela Hatchfield in 1989. In discussions with the Museum's painters, as they report their experiences and conversations with the manufacturer, Camger Polyglaze 1-146 has been designed for spray application. Polyglaze 1-146-10 is a flat finish and 1-146-50 is a satin finish. It is normally cut with water, two parts polyglaze 1-146 to one part water. In a brush application on a large surface it is very hard to use, because of the speed with which it dries. Our painters' preference currently is to use the basic resin in Polyglaze 1-146, Sancure number 878. They report that even when diluted ten parts Sancure to nine parts water, as is normally done, its drying time is slow enough to get both good saturation and reasonable leveling. Sancure, which is manufactured by Sannor Industries, Inc., 300 Whitney Street, P.O. Box 703 Leominster, MA 01453, tel. 508/537-4748, seems to be available through some local paint suppliers. We buy it from Dexter Brothers, Co., 86 Los Angeles Street, Newton, MA 02158, tel. 617/332-3434.

⁴Information available from Dow Corning Corporation, Midland, MI 48686-0994, tel. 517/496-6000.

⁵ Available from Voltek, 100 Shepard Street, Lawrence, MA 01843, tel. 508/685-2557.

slots cut in the front of plywood decks, or by "floating" or raising a plywood deck with blocks 3/8" to 5/8" above the compartment for air exchange around all edges.⁶

The internal silica gel compartments are generally accessible through a series of two doors. In a free-standing pedestal, this door is hinged as part of a side panel and opened with a spring catch. Inside, one finds an open lower space for weighing or attaching the pedestal to a gallery floor and the upper silica gel compartment that is accessed by its own hinged or screw fastened door (Figure 1). Much larger wall cases, which sit on the floor have, snap-on panels in the bottom front of the cases with similar secondary compartment doors inside (Figure 2).

In cases which hang on a wall above the floor or free standing cases that have legs, the silica gel compartments are accessed directly from the bottom of the case by a hinged door. In some instances high performance "Arten Gel Modules"⁷ (10" x 3" 100 micron porosity polyethylene canisters) have been successfully attached to the inside of these doors with electrical tiewraps made of plastic and stapled in place (Figure 3).

The system just described was developed for both large and smaller cases especially designed and built for the Museum's exhibit Ten Centuries of Courtly Splendor: Art Treasures from Japan. Although these objects were shown in climate controlled special exhibition galleries, the Japanese lenders required that all objects made of organic materials in the show be encased and maintained at 60% RH \pm 2% while bronze and other metals be kept at a much lower relative humidity. Because these fragile polychrome wooden sculptures, lacquer ware, hanging scrolls and screens were being shown in our galleries during late fall in New England, and the show's visitorship was unpredictable, the Museum's engineers felt that they could not meet the tight environmental requirements of the lenders with the gallery HVAC system alone. The challenge then became to tightly control relative humidity inside some very large cases. The largest of these cases was constructed mostly of plywood modules approximately 3' deep, 6' wide and up to 10' tall. The modules were splined together to form up to 24' of unbroken interior width. This volume of exhibit space plus the volume of the silica gel compartments underneath totaled 800 cubic feet to control in the largest case. Each case module required 40 one pound Arten Relative Humidity Control Modules for a total of 160 for the entire 24' case. To give the reader an idea of the scope of this project, one thousand four hundred and thirty of the Arten canisters were used in this one exhibition!

⁶ For a more detailed discussion of this subject see "Fixtures at an Exhibition Part II: Microclimates with Silica Gel: Efficiency Testing of Deck Designs", by Ann Boulton in this publication.

⁷ Made by Art Preservation Services, 253 East 78 Street, New York, NY 10021, tel. 212/794-9234.

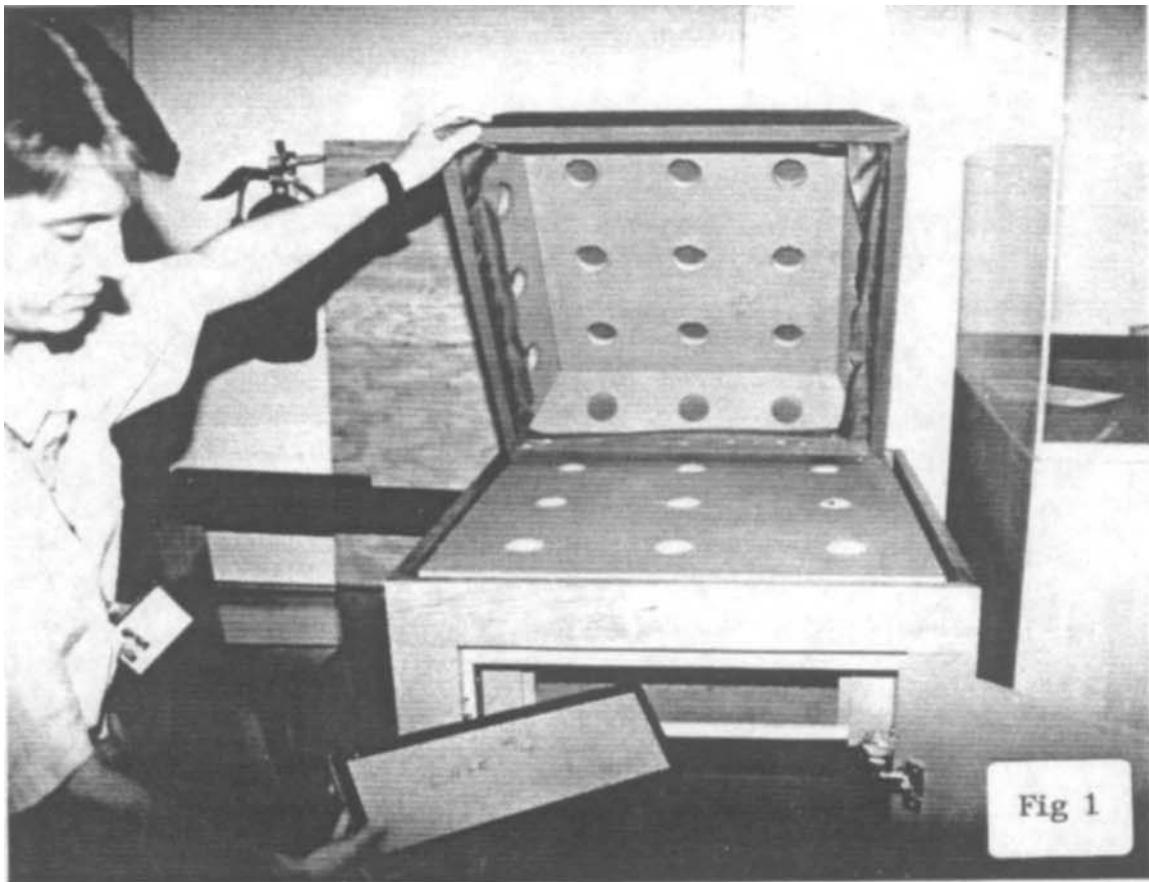


Fig 1

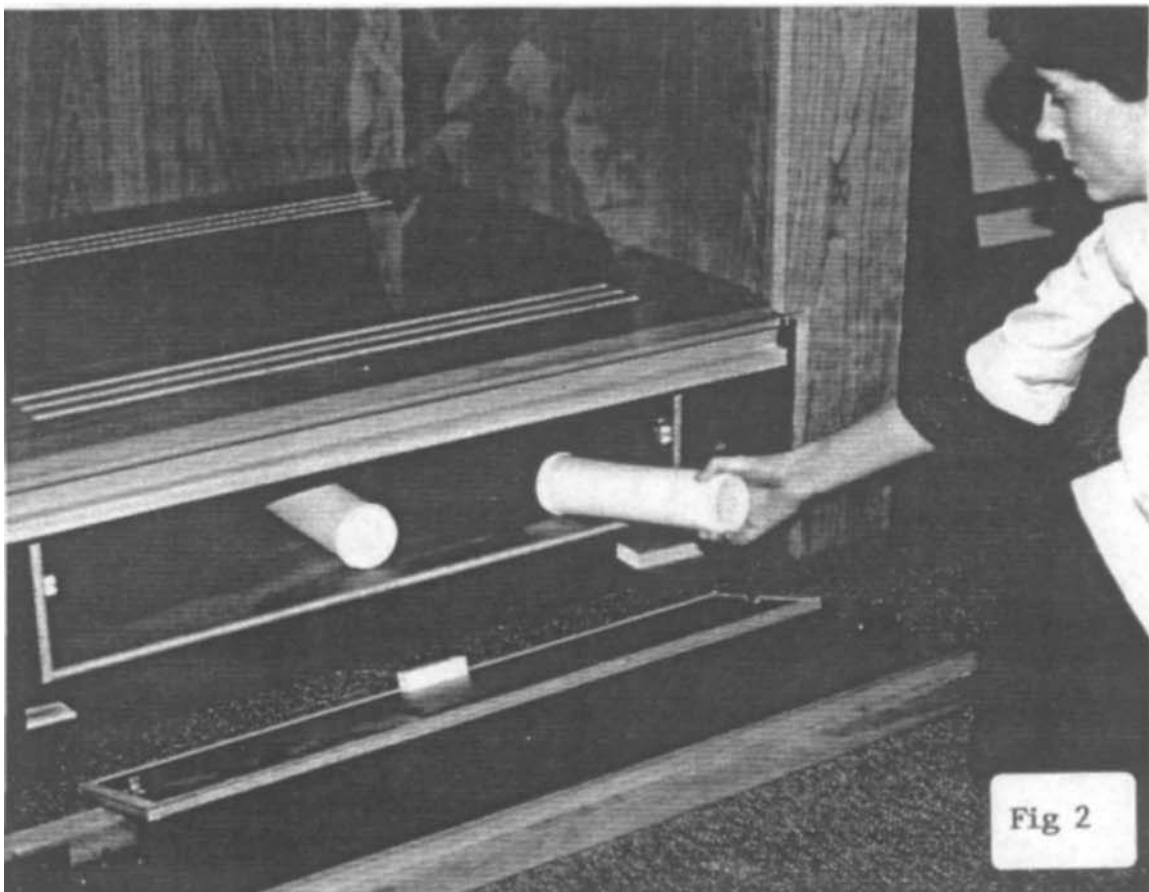
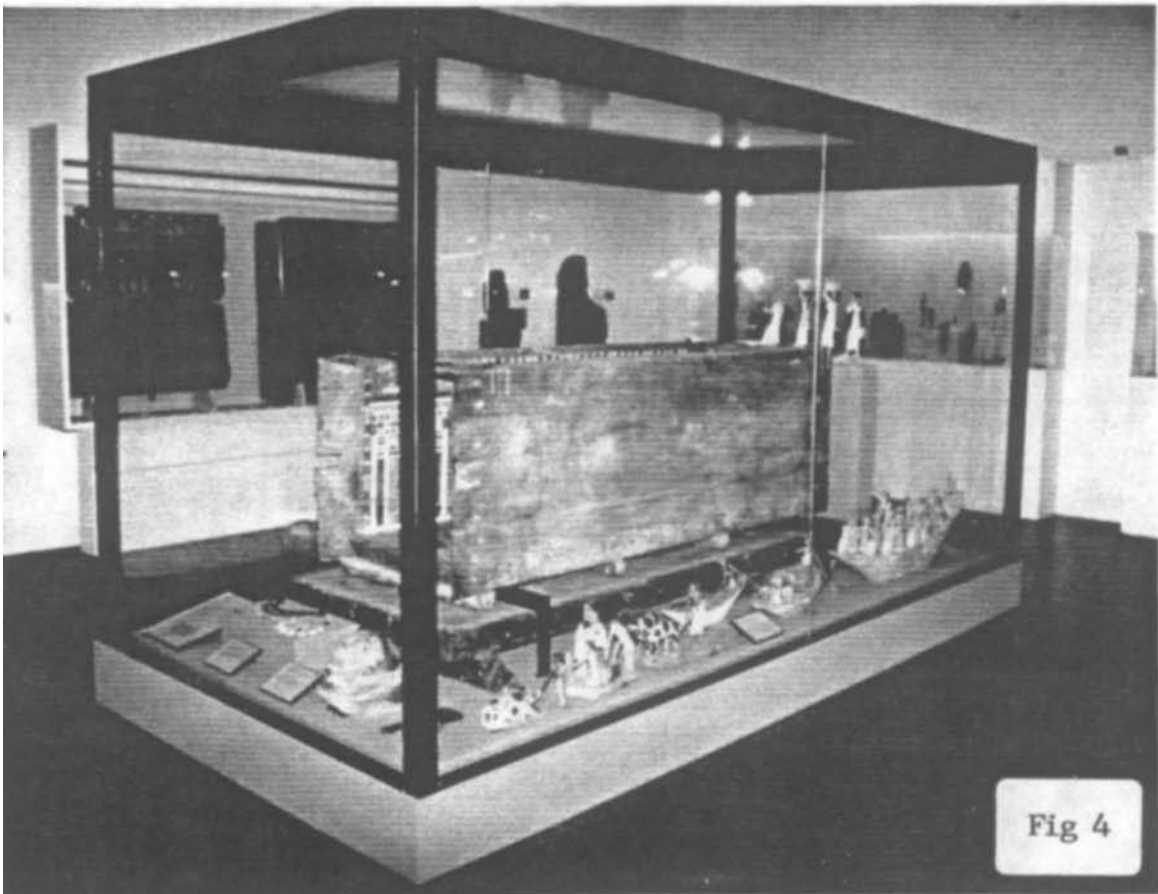
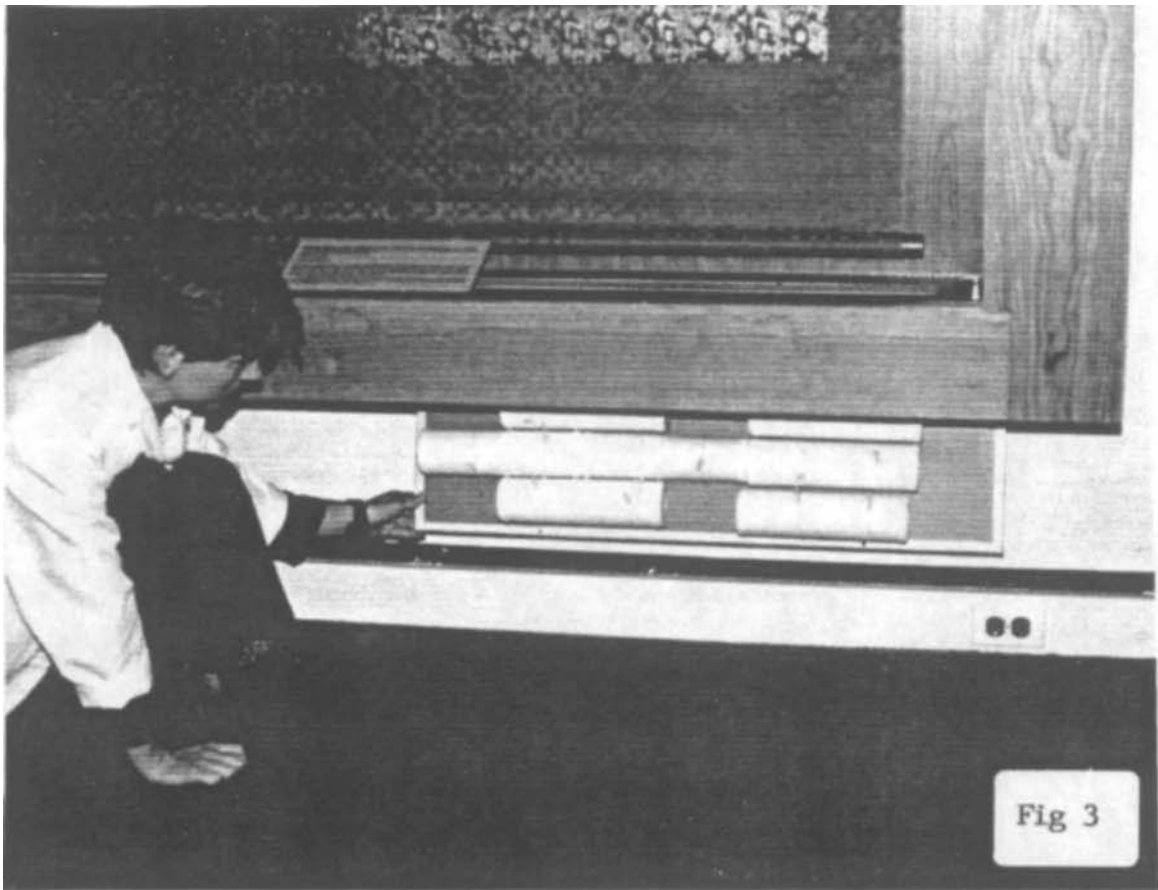
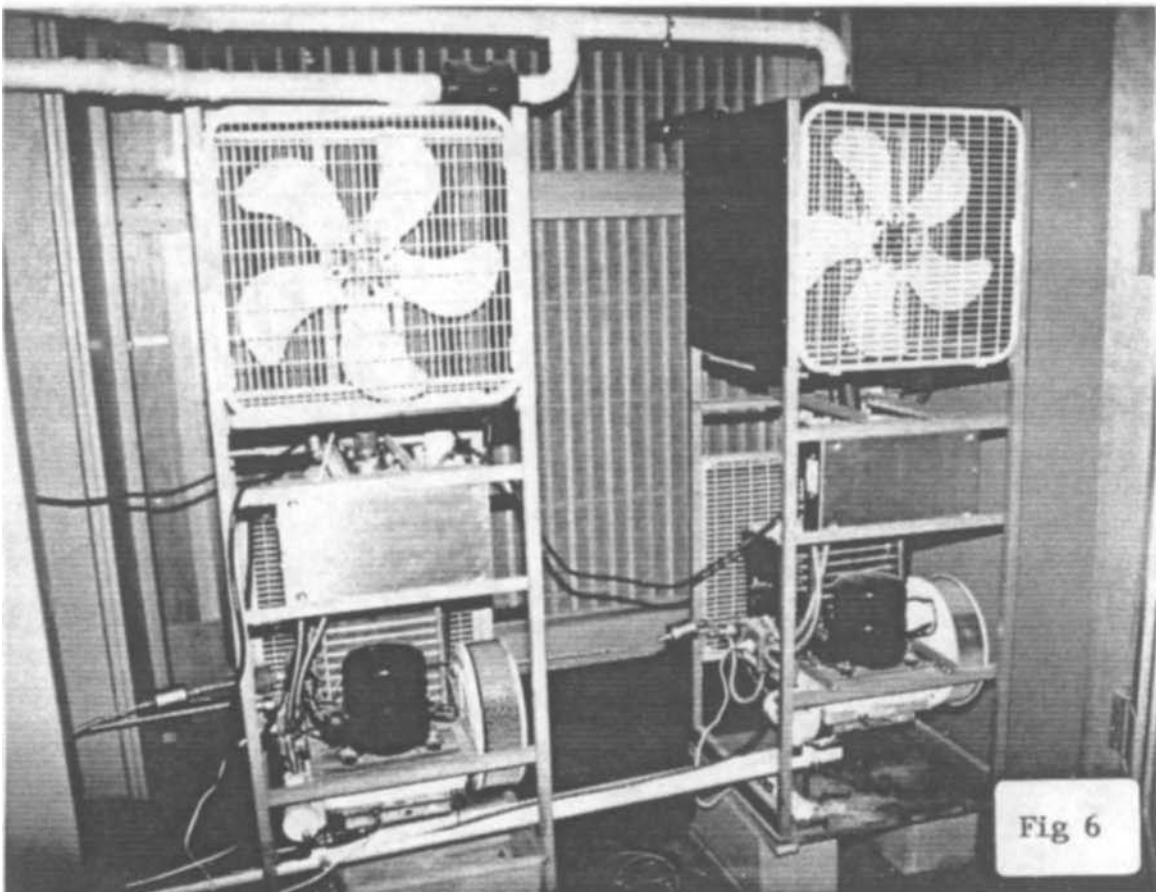
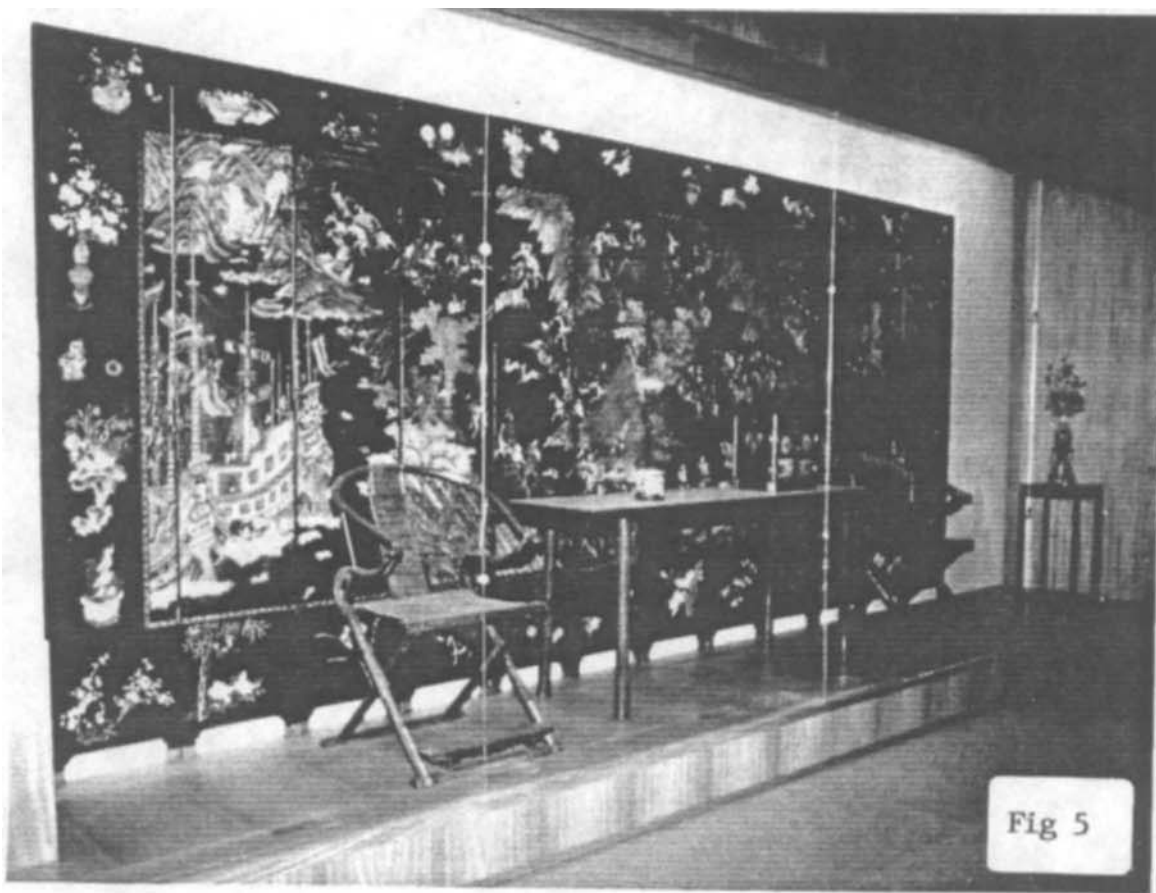


Fig 2





In order to make these cases as air tight as possible, in addition to the case construction details already mentioned, three other materials were used. These were principally employed to seal either the large movable plexiglass door fronts or smaller movable sloping plexiglass panels on very long 30' hand scroll cases. Once fixed in place in order to seal the separate plexiglass pieces, butt joints were covered with 3/4" wide J-Lar clear tape.⁸ At the perimeter edges where plexiglass was fitted behind wood, two very different types of flexible tubular gasketing were used, polyethylene HRR backer rod or Green-rod⁹ from the construction industry and various sizes of silicone tubing from a laboratory supply house.¹⁰

The Arten Gel Modules were all preconditioned to 60% RH before being placed in the cases. The relative humidity in the galleries was kept as close to 60% RH as possible for several weeks before and during installation of the objects and the Gel Modules. This allowed the casework and room furnishings to equilibrate at 60% RH. Once the cases were gasketed, closed and sealed, humidity levels were further refined where required by installing open 4 oz. glass jars of water inside the silica gel compartments. The jars were closed with their screw-top lids when the desired humidity level was reached, usually in about 12 to 24 hours. The hand scroll cases presented the only persistent difficulties in maintaining 60% RH. Although the ballasts for the internal fluorescent lights were not placed inside these cases, the lights themselves gave off enough heat to cause a 2% to 5% RH drop in relative humidity when they were on. To correct this problem, water jars were left open and filled most of the time as makeup moisture in these cases. In addition we used cotton wicks in the water jars to accelerate the rate of evaporation.

These passive systems and cases worked extremely well in this application in climate controlled spaces even when swings of as much as 20% RH in twelve hours were experienced in the galleries. However, most of the larger cases built for "Courtly Splendor" are not airtight enough to work efficiently in the non-climate controlled parts of the Boston Museum. In these older galleries other cases have been devised. For example, we have very successfully used the Arten Gel Modules to hold a 50% steady relative humidity for nearly a year without any reconditioning in a large 12' x 6' x 6' case in our non-climate controlled Egyptian Galleries (Figure 4). The basic difference in this case is that the plexiglass elements are fixed and not easily movable. This is a "permanent" installation where accessibility is not as much of an issue as it is with temporary exhibition hardware.

⁸ This tape comes in various widths and is made by Permacel of New Brunswick, N.J.

⁹ Green-rod is made by nme, inc., 51 nme Drive, Zebulon, N.C. 27597, tel. 800/345-7279. It comes in eight diameters from 1/4" to 1 1/8".

¹⁰ Silicone tubing No. L-06411-62 Cole Parmer Instrument Co., 7425 North Oak Park Avenue, Chicago, IL 60648, tel. 800/323-4340.

Finally, I would like to briefly describe how we have successfully been able to create a very stable environment by active means in several very large cases of a similar design to those made for "Courtly Splendor". These two large 33" x 9' x 30' long cases each containing about 850 cubic feet of air are connected to two Kennedy-Trimnell Relative Humidity Control Modules, Model No. 3 (Figures 5 and 6).¹¹ The cases are located in the Bernat Galleries for Chinese art which are not climate controlled, but also not surrounded by any exterior Museum walls. Internal incandescent case lighting is isolated from the exhibit space and vented with fans and ducted to an attic. The conditioned air from the Kennedy-Trimnell units is piped through 2" ID PVC to balancing valves located every 6' over the cases and reduced down to 1/2" silicone flexible tubes which enter the cases through a translucent plastic ceiling panel below the lighting compartment.

Since much has already been written about the Relative Humidity Control Module, I will only report here on our specific findings.¹² We tested a Kennedy-Trimnell unit for about a month in the spring of 1989.¹³ A 468 cubic foot exhibition case similar to the one shown in Figure 4 was connected to the unit with a 2" PVC pipe. The room in which it was tested contained a heat source, air-conditioning unit, humidifiers and de-humidifiers. By using these climate control devices we were able to simulate conditions in our non-climate controlled galleries through all seasons. Room temperatures varied from around 70° to 96° Fahrenheit. Relative humidity in the experimental room ran from a low of 43% RH to a high of 65% RH. Although the experiment was not run under ideal circumstances or for a long enough period to get good statistical information, we were satisfied that the Kennedy-Trimnell Relative Humidity Control Module, Model 3 had applications in our Museum. The most significant finding was that it performed better in conditions of moderate to low relative humidity than it did at higher relative humidities such as we experience in our galleries when windows are opened for ventilation in the summer. As a result we ultimately installed the units, as have been mentioned in galleries, in the center of the Museum that do not have outside windows and which are in addition half bordered by climate controlled spaces. I would characterize these Chinese galleries as having fairly stable temperatures throughout the year, but their relative humidity can vary widely and be especially low in the winter. Since we were showing very important Chinese lacquer ware and wooden furniture in these cases, RH control at 55% \pm 2% RH was imperative.

¹¹ Kennedy-Trimnell Company, 109 North Kenilworth Street, Oak Park, IL 60301, tel. 708/386-6476.

¹² The most recent article is found in the Journal of the American Institute for Conservation Fall 1991, Volume 30, No. 2, "The Development of the Humidity Control Module at Field Museum", Cathrine Sease pp 187, 1960.

¹³ This research was conducted by Margaret Leveque, Associate Conservator in the Research Laboratory of the Museum of Fine Arts, Boston.

Four large cases were originally designed to be installed in these galleries. Although their total cubic footage did not exceed the stated upper possible capacity of 5500 cubic feet of one Kennedy-Trimnell unit, based on four air changes per day, we decided to install two units to be on the safe side. In addition we plumbed them in such a way that by turning air control valves one unit could serve all the cases if the other was down for servicing (Figure 6). One of the four cases was not built, but still might be at a later date. A third case currently contains ceramics and is not actively on the system.

Our conclusions about the use of this active system for the control of relative humidity in large exhibition cases is not very different from those stated by Catherine Sease in her recent AIC Journal article. Our units have been operational for about two years. We allowed a full month to balance the system before putting objects in the cases. We too have experienced problems with our water supply and mineral deposits in the steam pans, although not as severe as those reported in Chicago. We plan to install some type of filtration and deionizers in the water supply in the near future.

When we installed these units originally we assumed them to be a stop-gap measure for five to ten years by which time state-of-the-art climate control would be installed in these Chinese galleries. With rough estimates of between 50 and 60 million dollars now being given to renovate and climate control the half of the Museum yet to be done, some new thinking may be in order. We are seriously considering the use of well designed, sealed exhibit cases for some of the permanent collections where internal climates are controlled by refined active and passive systems such as the ones just described. Achieving gallery climate stability may not be affordable for years to come.

Acknowledgements

Projects of the magnitude just described do not happen without the participation of many people. I am particularly grateful to Museum Designer, Tom Wong for his incredible memory and attention to detail. Warren Young, Assistant Director of Facilities, has been responsible for seeing to the successful design and operation of this active systems. Proprietors, Steven Weintraub and Ralph Trimnell were most generous with their time and advise. And finally, I would like to thank Pam Hatchfield, Associate Conservator, for her encouragement to report on these findings and her editorial assistance.

"Gaseous and Particulate Filtration for the Pinkney House at the Kern County Museum"

ABSTRACT

The Pinkney House is typical for many of the historic structures at the Kern County Museum. It has problems with particulate and gaseous contamination, and lighting problems. Typical "environmental controls" of heating, cooling, humidification and dehumidification were ruled out, based on the priorities identified for the collection as recommended by the conservator, and the prospects of the high capital and operating costs of treating over thirty such structures at the museum.

Since the environment within the house is not occupied, only viewed by visitors from outside, an innovative approach was used to improve the conservation environment within. First, the building was sealed to prevent entry of particulate and gaseous contaminants. Second, an air filtration system was installed to remove particulate and gaseous contamination from the circulated air, and to introduce a small amount of filtered outside air for pressurization. Third, the display cleaning program was improved to include a vacuum with a high-efficiency particulate filter.

The Pinkney House improvements were developed as a prototype to identify effective solutions for roughly thirty other such structures at the Museum.

The paper presents details of the improvements, with before and after observations for particulate and gaseous contamination. The paper also discusses measures to consider for further work and investigation.

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Paper Review and Comment by:

Ms. Carolla Enriquez, Director, Kern County Museum;

Mr. David R. McCauley, Assistant Director and Registrar, Kern County Museum;

Ms. Mayda Jensen, Conservator.

Submitted to:

Ms. Pamela Hatchfield, Objects Group Program Chair, Museum of Fine Arts, 465 Huntington Avenue, Boston, MA 02115

BACKGROUND

The Kern County Museum is a collection of artifacts and buildings from the Bakersfield area, representing historic activities and structures. The Museum collections are kept in the various buildings, exhibited either in one of the modern buildings, such as the Main Museum Building, or one of the various historic structures.

The Pinkney House is typical of the historic structures, a former residence. The collection is exhibited inside the house and visitors view the collection by way of a glass "view box" which opens onto the kitchen and living room. Museum visitors may also view the collection through the several windows which afford a view into the kitchen, living room and bedroom.

CONSERVATION ENVIRONMENT PROBLEMS

The consulting conservator, Ms. Mayda Jensen, surveyed the Museum and collections and identified basic priorities for environmental improvements. Humidity extremes, high light levels, high temperatures, particulate and gaseous contamination were cited.

GASEOUS CONTAMINATION. The major acute threat posed to the collection is from the more recent gaseous pollution in the Museum's region, which the conservator has identified as a primary agent in damaging most parts of the collection. The pollution and oil drilling in the San Joaquin Valley in and around Bakersfield has led to high pollution levels, aggravated by the containment of the Valley mountains and frequent thermal inversions.

PARTICULATE CONTAMINATION. A major problem was particulate contamination, primarily due to the dusty areas surrounding the Museum, including the adjacent fairgrounds. The chronic problem of ambient dust presents a lesser real threat to the collection's well-being, but considerably diminishes the value of the collection to the viewer.

Cleaning of the collection had previously been done with cloth, feather dusters and portable vacuums. Areas generally needed recleaning in less than 6 months.

HUMIDITY STABILITY AND LEVEL. Due to the high rate of infiltration in the buildings the humidity follows outside conditions. This leads to daily fluctuations and prolonged periods of high humidity when rains occur. Unlike many museums where humidity control is the primary goal, much of the Kern County Museum historic collection has, by definition, already been generally exposed and acclimated to the Kern County ambient environment. The Kern County climate does not present the extremes in humidity found in many other climates, and the lack of low temperature extremes reduces the tendency of extreme drying from heating. There are, however, ambient fluctuations in humidity to which the conservator attributes some of the collection damage.

PROJECT CONSTRAINTS

CAPITAL BUDGET. The Museum has a very limited capital budget, highly dependent on county funding and grants. As such, the cost of major improvements to the many buildings needing attention would likely be prohibitively expensive. Over thirty buildings treated at a cost of roughly \$20,000 each for conventional HVAC systems would yield an eventual project cost of over \$600,000.

UTILITIES INFRASTRUCTURE. There is very limited utilities infrastructure throughout the Museum grounds, usually limited to 10- or 20-amp/120 volt single-phase electric service. Although available on site, no gas, water or drains are brought to most buildings. To provide such distribution infrastructure might easily double the project capital cost.

OPERATING BUDGET. Even if the Museum could afford the cost of the conventional HVAC equipment, it would be hard pressed to come up with the annual operating costs which might amount to a six-figure recurring annual cost.

TREATMENTS IDENTIFIED AND IMPLEMENTED

Typical "environmental controls" of heating, cooling, humidification and dehumidification were ruled out, based on the priorities identified for the collection as recommended by the conservator, and the prospects of the high capital and operating costs of treating over thirty such structures at the museum.

SEALING OF THE BUILDING. The building was sealed with caulk and repainted. Operable doors were gasketed and inoperable doors and windows were sealed.

IMPROVED VACUUM CLEANING OF THE COLLECTION. A new type of vacuum was used, equipped with a higher-efficiency "toner" bag to trap smaller particulates.

PARTICULATE FILTRATION AND GASEOUS CONTAMINATION CONTROL. A recirculating air-handling system was installed with high-efficiency particulate and gaseous filtration. A small amount of outside air was introduced at the inlet side of the system for slight pressurization of the building, hoping to encourage exfiltration rather than infiltration through any remaining cracks in the building.

TREATMENTS ASSESSMENT

PARTICULATE CONTROL. The Museum noted a dramatic improvement in particulate contamination. Rather than being badly in need of cleaning in less than 6 months, the building needs very little cleaning almost a year after installation of the system. The Museum noted that the particulate filter needed changing about one month after the unit was in operation, but that after that the filter seems to be providing a longer

life, indicating that the primary filter loading was from initial original dust which has now been removed with very little dust entering to take its place.

The new vacuum cleaner also seems to be doing a better job of removing the particulates, trapping the smaller particles rather than blowing them through the bag and back into the collection space.

GASEOUS CONTROL. Methods measuring of gaseous contamination levels were only very crude tarnish observations on silver and did not include any laboratory-grade pollution tests or testing of individual collection objects damaged by gaseous pollutants. Nonetheless, silver test objects in the Pinkney House showed improved tarnish protection when compared to similar test objects in the similar but unsealed and unfiltered Dressmaker building.

HUMIDITY EXCURSION REDUCTION. The extremes of humidity often experienced in the past have not been evident in the renovated Pinkney House. However, the House undergoes regular daily fluctuations in humidity coincident with the diurnal temperature fluctuations typical of an unheated/uncooled building.

CONCLUSIONS

The Pinkney House experience leads to the following conclusions.

1. **PARTICULATE CONTROL.** The use of central high-efficiency particulate filtration, combined with higher-efficiency cleaning vacuums, can lead to a dramatic reduction of particulate contamination, and an associated major reduction in collection cleaning efforts.

Filtration treatment of each room in a small building is evidently not necessary so long as the central system move a sufficient volume of air (over 1 cfm per square foot).

Use of an expensive HEPA vacuum (\$700-\$1,000) is evidently not necessary. A small "toner" vacuum (\$150) is evidently effective.

2. **GASEOUS CONTAMINATION CONTROL.** The use of central gaseous filtration with potassium permanganate pellets is evidently effective in reducing the rate of tarnish on silver objects and may indicate a reduction in long-term damage to other objects damaged by gaseous contaminants.
3. **METHOD OF GASEOUS CONTAMINATION MEASUREMENT.** A more precise but economical method of measuring gaseous contamination levels in the field would be desirable. Faced with the tarnish-on-silver technique, differences are better seen on flat silver objects, such as butter knives, rather than complex objects, such as spoons and forks.
4. **SEALED BUILDINGS AND TEMPERATURE/HUMIDITY SWINGS.** A sealed building can be expected to exhibit diurnal humidity swings psychrometrically

reciprocal to diurnal temperature variations. The diurnal temperature swings of a similar unheated/uncooled building can be expected to be about 4 to 6 degF warmer than for an unsealed building.

FURTHER WORK

Although important conclusions can be reached from the Pinkney House renovation project, it also highlights other issues deserving further attention.

1. DEGREE OF CONTINUOUS GASEOUS TREATMENT REQUIRED. Although effective, it is not clear that the \$2,000 installation at the Pinkney House is either too little or too much treatment. More or different gaseous media might prove more effective. On the other hand, long-term protection might be adequately provided with smaller \$600 or less filtration systems with less media.

This could be easily determined by testing the gaseous contamination levels in two buildings treated with each type of system.

METHOD OF GASEOUS CONTAMINATION MEASUREMENT. A reliable, accurate method of measuring gaseous contaminant levels in the field is needed to help determine the adequacy of the gaseous treatment.

This might be achieved using one of the new continuous corrosion indicators now available commercially for less than \$10,000, or with one of the low-cost passive testing devices just now becoming available.

2. DEGREE OF CONTINUOUS PARTICULATE FILTRATION REQUIRED. Since the primary loading of the fine particulate filter was in the initial weeks of operation, the amount of continuous particulate filtration required may be less than that required initially. Long-term protection might be adequately provided with smaller \$600 or less filtration systems.

This could be easily determined by testing the particulate contamination levels in two buildings treated with each type of system.

METHOD OF PARTICULATE CONTAMINATION MEASUREMENT. This might be achieved using one of the portable laboratory-grade particulate samplers available commercially for less than \$2,000.

3. TREATMENT OF HUMIDITY SWINGS. The diurnal humidity swings of a sealed building may present a long-term problem to the collection, although no evidence has been presented that they are any worse than the humidity extremes of a leaky building. If identified as problematic, treatment of the swings may be possible.

BUFFERING MATERIALS. The current humidity swings are not entirely psychrometrically reciprocal to the temperature swings - they are

less than would be indicated by a pure temperature-driven change. This indicates that there may be a buffering effect in the building, possibly the wood structure itself, reducing the humidity swings. This effect might be enhanced by the introduction of more stabilized humidity buffering materials, such as silica gel.

HUMIDIFICATION. Although dehumidification might be problematic in capital and operating costs, modest humidification might be considered to increase humidity during the low part of the swings. Since the humidity is relatively low (35% RH rather than 50% RH), a wetted media device, such as wetted rotating copper screens, might be added to the system for humidification. The humidifier could be controlled by a low-level humidistat, turning the device on only when humidity falls below the peak or average humidity in the typical daily swings.

However, humidification should be carefully tested. Unlike a buffering material, it will lead to a net increase in humidity, which might end up increasing the average humidity without reducing the peaks.

COOLING. The primary cause of the humidity swings is the change in space temperature. As was planned in the event of over-heating, the building might be cooled with one or two indirect evaporative cooling cells, controlled by space temperature. While this would require a greater capital cost for the cells and cooler scavenger air fans, it would be less than half the cost of a conventional vapor-compression cooling system and less than one-tenth its operating cost.

DETAILS ON TREATMENT EQUIPMENT USED

TONER-RATED VACUUM CLEANER: Metro "Data-Vac II" with optional toner bag installed.

PARTICULATE/GASEOUS FILTRATION SYSTEM: Thurmond "IAQ" filtration system.

Air Flow: approximately 2,000 cubic-feet-per-minute (CFM).

Gaseous media: 1 cubic foot of alumina pellets with 4% potassium permanganate loaded into "V" cells.

Particulate media: 2" Farr 30/30 30% Efficient Prefilter (or equivalent), 12" Farr Riga-Flow 200 90-95% Efficient Final Filter (or equivalent).

The scope of this paper was limited to particulate and gaseous filtration issues for the AIC Meeting at the request of the Objects Group Chair. Once new windows are installed in the Pinkney House the paper is intended to be expanded to include the lighting treatments and submitted to the AIC Journal.

ARCHAEOLOGY/ETHNOGRAPHIC SMALL GROUP DISCUSSIONS

Abstract

Christina Krumrine

"Use of Teflon tape in the conservation of a Navajo cradle"

Ms. Krumrine described her use of Teflon "plumbers" tape to repair a Navajo cradle. To re-adhere delaminating bark, warm gelatin was applied between the bark and twigs. Strips of flexible, non-stick Teflon tape, an inert polytetrafluoroethylene (PTFE) polymer, were wrapped around the twigs. The tape provided gentle, even pressure to the bark during drying of the gelatin. Gortex gasket tape, another brand of PTFE polymer available in varying thicknesses, has been successfully adhered to brass mounts with archival adhesive; it provides a non-abrasive cushion for objects with friable paint layers.

Abstract

J. Claire Dean

**"The protection and conservation of archaeological sites and their contents:
Pinon Canyon Maneuver Site, Colorado"**

Ms. Dean, an archaeological site conservator, presented the problems faced in attempting to conserve archaeological and historical sites at Pinon Canyon Maneuver Site. While many of the problems were common to the conservation of all types of site, unique to Pinon Canyon is the potential destruction caused by the mechanized training of tank crews. Such training can cause extensive damage to rock art, archaeological and historic sites. Ms. Dean reports that the US Army has been very conscientious in avoiding this problem, and is working closely with various agencies to preserve the cultural resources at Pinon Canyon.

Abstract

Mr. Gary McGowan

"The South Street Seaport Museum Archaeological Conservation Laboratory"

Mr. McGowan reviewed the history of the South Street Seaport site and the legal decision resulting from litigation between archaeologists and developers, which provided at least a five-year presence of a conservation facility for which he is responsible. He reviewed the large numbers of artifacts which the facility is attempting to stabilize and exhibit, focusing on a number of interesting treatments. The presentation outlined the problems faced by a small facility with a very limited amount of time to assure the preservation of a large number of archaeological objects. Mr. McGowan also reviewed the challenges and benefits of working in facilities where the conservator is asked to interact with the public while working on the artifacts themselves.

Abstract

Joan Schiff

"The conservation of iron buttons from the Bowne site."

Ms. Schiff, a conservator at the South Street Seaport Museum, described the specific treatments being attempted to conserve mid-19th century corroded iron buttons, from an excavation formerly at 75 Wall St. Mechanical cleaning, removal of chlorides through soaking, vacuum impregnation with B-72 and/or wax, tannic acid application, etc. are stabilization techniques which have proved effective. The buttons will be stored in new environmentally controlled storage.

Abstract

T. Rose Holdcraft

"Repair of a Hawaiian Crested Feather Helmet"

A brief presentation on a treatment designed by Scott Fulton and T. Rose Holdcraft, illustrated the use of a narrow diameter surgical polyethylene tubing in the support of a tear in the cap portion of the helmet. The tube's function was to inhibit extension of the tear during transport and exhibition at a loan show. The beneficial properties of the tube are its inherent flexibility, low weight and low elongation. Discussion followed regarding potential use of other materials, including teflon tubing and the wide possibilities of their use as stable supports.

Abstract

Dennis Piechota

"An RH stabilized case using a gelled saturated salt "gatekeeper."

Mr. Piechota presented for discussion a concept he has been developing which would allow the reconditioning of silica gel within a sealed case by the introduction of various gelled metallic salts accessed via a small port. Gelled salts in Tyvek packets would either dessicate or humidify the air as it passes into the case. Mr. Piechota described his success in gelling zinc nitrate (43%RH) with Methocel A4C.

June 8, 1991

John Griswold, from Glenn Wharton and Associates, Santa Barbara, California, showed samples of a translucent filling material his company has been using for outdoor marble sculptures. It is made with Hxtal NYL-1 epoxy (from Conservation Materials), Cabosil (fumed silica), and #5 White Hard Fusing Powder (from Thompson Enamel, Box 310, Newport, KY 41072, tel. 606-291-3800). The enamel powder allows brilliant whites to be achieved without losing translucency.

He mixes the epoxy and then adds Cabosil, 4 or 5 times the volume of the epoxy. It must be very well mixed; an electric rod is useful. The filling material is ready to use when it becomes a stiff, translucent paste. Just enough white enamel frit is added to produce the appropriate shade, which can be slightly modified with small amounts of dry pigment.

Hxtal is used because it is not supposed to yellow. He has not yet experimented with added UV inhibitors. The kind of fillings shown have not been outside for more than a few years but they have not changed color. Hxtal setting speed is variable. It depends of the amount of hardener, the heat and relative humidity.

Griswold pointed out that #5 frit contains lead as a modifier within the glass but that this should not have any effect on long term aging properties, according to John Twilley at LACMA. Normal health precautions should be observed while using it, especially when sanding the final putty.

Discussion followed about various stone fillings, everything from lime mortar, to proprietary products and resins with various aggregates.

Shelley Sturman raised the question of adding UV absorbers (such as Tinovin 328) to coatings to stabilize them, especially in an outdoor environment. These UV absorbers are based on benzotriazole derivatives. She does not know of many people working on this and hopes to begin research. Any suggestions will be welcome.

Tracy Power reported that she and Michelle Barger had experimented with various fillers. (The following text follows from notes Powers sent in after the meeting). The experiments were conducted while treating an indoor alabaster sculpture at the Fine Arts Museums of San Francisco. They wanted to avoid

using solvents since solvents lead to shrinkage and can have negative effects on aging of resins. Solvent retention in the fill material could make the fills too soft and inappropriate for large fills along protruding design elements. The fill material also needed to be translucent to visually blend with the stone.

Solvents were avoided by melting mixtures of synthetic waxes and solid resin beads in small metal weighing cups over a hot plate. Calcium carbonate and alabaster dust were added for coloring, and fumed silica was added as a matting agent. The mixtures were cooled and they hardened into separate cakes.

Poly (vinyl acetate) resin beads and solid synthetic waxes were tried first, yet were unsuitable as they separated upon cooling in the metal cups. The process was repeated using resin beads without wax. A range of poly (vinyl acetate) resins and Acryloid B-72 resin were experimented with, and all had the qualities initially desired from the fill material. Acryloid B-72 was chosen for the treatment because it seemed to have better working properties.

Before applying the fill material, damaged areas on the stone were primed to promote better adhesion, with a layer of poly (vinyl acetate) in ethanol. A heated spatula with various tips was used to soften the thermoplastic resin to work it into areas of loss on the sculpture. A combination of differently tinted resins were used to simulate variation in stone. The fills were refined by use of heat, solvents, and polishing.

The technique requires some patience, yet Power and Barger feel that the visual result, avoidance of toxic solvents and promise for long-term stability outweigh the inconvenience. Although the sculpture treated is exhibited indoors, the technique may have a potential for stone exhibited outdoors. Other thermoplastic resins could be substituted for Acryloid B-72. The technique has also been used successfully on ivory.

After the discussion about stone filings Arthur Beale gave an update on the SOS! program. Update material written by SOS! since the Albuquerque meeting is appended to these notes in lieu of a summary of the informal remarks made in June.

After Beale's presentation Terry Weisser commented that there are too few practitioners in the field of outdoor sculpture conservation. [Hear! Hear!]

David Mathieson brought up the subject of treatment and display of deteriorated wooden sculpture outdoors. He is particularly concerned about figureheads. After some discussion everyone seemed to agree that historic polychromed wood should be brought inside. Many people thought placing replicas outdoors was appropriate. A discussion followed about suitable replication materials.

Beale mentioned the resin rhinoceros replica outside the School of the Museum of Fine Arts, Boston. It was cast from a plaster mold used to make the original bronze by Katharine Lane, located on the Harvard University Campus. Beale mentioned the extensive use of resin for reproduction of bronze and stone sculptures in France; delegates to the 1986 ICCROM metals conference in Paris were shown many examples. Naudé gave an example of replacement using similar material; medieval limestone carvings are being replaced by carving existing, weathered images in the same kind of stone using computer technology. Slides were shown of early prototypes in a process being developed by John Larson for Lincoln Cathedral in England.

Glenn Wharton asked the group if anyone could provide advice for some current projects on sculpture in fountains. People who had addressed this issue had generally used very practical means to get the purest water possible, by removing metal pipes, using antibacterial agents and monitoring water purity. The technology for purifying water through less chemicals and more filters exists but is very expensive. (Note: Martin Burke will present, at the 1992 AIC Pre-Session on outdoor sculpture, the results of his current research on fountain maintenance. He will provide maintenance guidelines and sources of information.)

There was discussion about increased legal restrictions on the materials we are allowed to use out of doors. Public health questions are being raised. Walnut shells and toluene were two frequently-used materials discussed. Beale mentioned that the coatings industry is very concerned about the same issues, and a considerable amount of research is underway to develop water-based consolidants and coatings.

Some of the particularly toxic, frequently-used materials are the polyurethane paints with very toxic catalysts, such as Imron, from Du Pont. Many paint companies make a similar product.

The discussion went on about the quality of the Imron surface and aesthetic problems with its extreme gloss. Several people reported ordering matte Imron from the manufacturer. Marianne and Robert Marti reported work spring 1990 on a Calder sculpture at the Nelson-Atkins museum in Kansas in collaboration with Kate Garland. Du Pont came up with an Imron mixture to match the color and surface sheen of Calder's original paint. In this case the paint was not matte.

Du Pont has not done any tests on the life of the matte paint because of the high cost of testing and low demand for the product. The manufacturer says that the high gloss Imron has a coating life of 10+ years. They recommend, as we do, yearly inspections and spot retouches.

A few minutes were taken at the end of the afternoon for discussion about the discussion -- if people want to continue this kind of session at annual Objects Group meetings. There was

a consensus of "yes" and an interest in keeping the format fairly unstructured. It was suggested that someone sign up to give a starter presentation. Griswold's idea for a practical discussion with samples to pass around got everyone involved right away. People might also be encouraged to bring some slides to show if the discussion drifts in the right direction. It was stressed that maintaining spontaneity is very important.

The secretary was not aware that such an extensive commentary would be solicited for a post-print and suggests that the next secretary make better note of individuals who may have commented only briefly on a topic but who might be able to provide additional information to insert in the published notes.

AIC 1991 Albuquerque
Objects Session
Decorative Arts and Sculpture discussion group
Brian Considine, Secretary

Notes on the proceedings:

Kathryn Klein
J. Paul Getty Museum
213 459-7611
A Conservation Treatment for an 18th Century Chandelier.
Abstract attached.

Valentine Talland
The Isabella Stewart Gardner Museum
617 566-1401
Discussed the problems encountered in the consolidation of stone sculpture permanently installed in the museum. A vapor chamber was created by building a 2 x 4 frame and covering it with two layers of polyethylene sheeting. This chamber was then ventilated to the outside by installing a portable duct fan in a window and connecting it to the vapor chamber via flexible ducting. Sandbags were placed along the bottom to ensure a good seal. The exhausted air was filtered through charcoal and hepa filters. This chamber allowed them to contain the consolidant being sprayed on the stone.

Melissa Meighan
Philadelphia Museum of Art
215 787-5418
Italian High Renaissance Majolica: Examination and Treatment.
"Italian Renaissance" Hand Mirror: An Electrotpe.
A Tip for the Examination of Restored Ceramics.
Abstracts attached.

Don Menvig
Los Angeles County Museum of Art
213 857-6166
Discussed Toshikatsu Endo's sculpture, Lotus II, from the Hara Museum in Tokyo. This sculpture, which the artist describes as being of earth, air, sun, water, fire and wood, is made of 16 sections of charred wood with a circular steel water trough. The piece was in a travelling show and, because it had been made with green wood which was then charred, there were problems of cracking and crumbling of the charred sections. Leaks also had developed in the steel trough, which was lined with an industrial product called liquid membrane (manufactured by the W.R. Grace Co.). Shrinkage of the wood also caused the rag bond on the top of the wood to delaminate. This was reglued with PVA. The

artist had originally used latex to fill cracks on the exterior of the wood sections, but it was found that the latex pulled off too much of the charred wood when the piece was disassembled. Papier maché with clay was substituted in subsequent installations.

Kory Berrett
Berrett Conservation Studio
215 932-2425
and

Michele Barger
215 384-3624

Discussed the use of the scanning electron microscope to identify mold spores appearing on two tin-glazed earthenware objects. Different molds were identified, including one that was growing under the glaze.

Jean Portell
Jean D. Portell, Inc.
718 643-1222

Discussed her current work on the recognition of decorative silver gilding when it is so tarnished that its presence is not obvious. She illustrated her talk with both sculpture and decorative arts.

Suzanne Hargrove
St. Louis Museum of Art
314 721-0067

The Examination and Treatment of a Behrens Electric Kettle.
Abstract attached.

Kathy Klein
The J. Paul Getty Museum
213 459-7611

Abstract

A Conservation Treatment for an 18th Century Chandelier

The main structural frame of this 18th century chandelier consists of four iron arms overlaid with rectangular pieces of glass which extend from a central iron spindle. Secondary armatures are made of silvered brass set with glass, crystal beads and rock crystal drops. Many of the glass elements throughout the chandelier are backed with a silvered copper foil. The foils are painted primarily in transparent yellow-green or faded crimson, but there are a number which are painted either purple or topaz to simulate semi-precious stones. Blue, topaz and purple-colored glass beads as well as gilt-copper accents have been added throughout.

Prior examination had determined that the chandelier needed to be cleaned, due to the heavy amounts of surface dirt, tarnish and rust. Because the mixture of copper and brass wire showed extensive signs of deterioration, it was decided that the entire wiring system for the crystal drops, beads and glass pieces should be replaced with a more stable material.

Materials and Suppliers:

Micro
Spectrum Chemical Manufacturing Corporation
14422 So. San Pedro Street
Gardena, CA 90248

Pliable stainless steel wire
Bob Martin Company
2209 No. Seaman Avenue
El Monte, CA 91733

Melissa S. Meighan
The Philadelphia Museum of Art
215 787-5418

Abstract

Italian High Renaissance Majolica: Examination and Treatment

A pair of late sixteenth century Italian Renaissance majolica vases, in the istoriato-grotesque style, are undergoing examination and treatment in the Objects Laboratory of the Philadelphia Museum of Art, initiated by an inquiry regarding their attribution and authenticity from the British Museum. The project has involved the use of X-ray diffraction analysis, emission spectrography, neutron activation analysis and cross- and thin-section analysis as well as normal macroscopic and microscopic examination techniques. Other Italian majolica in the P.M.A. collection was examined for comparison and the Renaissance text by C. Piccolpasso, The Three Books of the Potter's Art, was used to elucidate aspects of the materials and techniques of manufacture. A few aspects of the examinations and treatment will be discussed.

Abstract

"Italian Renaissance" Hand Mirror: An Electrototype

A beautiful, parcel gilt-silver hand mirror was recently examined as a rare example of Northern Italian domestic metalwork, dated c.1500. X-radiography was the analytical technique which confirmed that the object was an electrototype. Library research revealed that electrototyping was commonly used in the nineteenth century by a number of manufacturers for the reproduction of works of art for educational purposes. In at least one case, a major museum both commissioned and collected these electrotypes. Visual clues, maker's marks, the X-radiograph of the mirror and the 1868 "Convention for promoting universal Reproductions of Works of Art for the benefit of Museums of all Countries" will be commented on.

Abstract

A Tip for the Examination of Restored Ceramics

In recent examinations of repaired and overpainted ceramics, infrared reflectography has proven a useful alternative to X-radiography.

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Abstract

The Examination and Treatment of a Behrens Electric Kettle

An important early twentieth century example of an electric teakettle designed by Peter Behrens for manufacture by the Allgemeine Elektrizitäts-Gesellschaft of Berlin was examined and treated. The surface of the kettle was disfigured by packing tape, fingerprints, grime and old polish residue. Parts of the heating element package were broken or missing. The treatment describes the removal of the tape with benzine and the cleaning of the kettle with Solvol Autosol metal polish. Flaking black paint on the underside of the kettle was consolidated with a 20% solution of Acryloid B48-N in acetone. Hot air and hot water were used to reoxidize the surface slightly prior to the spray application of several coats of Agateen 2B cellulose nitrate lacquer. The wooden handle on the lid was given a protective coat of wax and the cane handle was wrapped for protection during the oxidizing and lacquering processes. Neither was soaked. The heating element was also detached and treated separately. Mica contained within the package was broken in many pieces. Rust was removed from metal plates in the package with glass bristle brushes. The pieces of mica were encapsulated between sheets of mylar prior to reassembly. After treatment, the handle of the pot was unwrapped and the wax was removed from the handle of the lid.

