

PACKAGING OF MUSEUM OBJECTS: CRITERIA AND TEST METHODS FOR PLASTIC FILM SELECTION

TECHNICAL PAPER

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This paper is based on a presentation at the 8th Indoor Air Quality 2008 (IAQ2008) in Vienna, Austria, 17-19 April 2008.

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In German-speaking countries more than 90% of museum objects are stored in special depot areas. Many museums do not have the required space or funds to be able to use purpose-built depots with optimal conservation conditions.

In the context of a cooperation of Kunsthistorisches Museum Wien (KHM), Essl Museum (Klosterneuburg, Austria), Wien Museum (Modesammlung Hetzendorf / fashion collection), the Department for Conservation and Restoration of the University of Applied Arts Vienna, two producers of plastic films and the Austrian Research Institute for Chemistry and Technology (*ofi*) a research project was carried out which aimed at generating standard packaging solutions for museums and art collections, which can be adapted to meet a wide range of requirements. The packaging should provide an optimized storage of the objects by stabilizing relative humidity as well as ensuring protection against aggressive pollutants. A further motivation for the use of the packaging of objects in plastic films was the prevention of infestation by microorganisms and pests in the depot areas.

Practical packing tests were performed in which a great variety of objects – from small metal jewellery to entire carriages as well as large numbers of similar objects – were covered in different plastic films (PE [polyethylene] films, PE-EVOH [polyethylene-ethyl vinyl alcohol] films) and SiO_x [silicon oxide]-coated films for various reasons. This long-term project also included fundamental studies on the behaviour of packed modern organic materials (e.g. rubber) as well as tests of the permeability to different air pollutants of the individual types of film.

It was shown that all films chosen, i.e. PE, PE- EVOH and ceramic-coated films, fulfil the corresponding requirements: the objects packed in plastic were sufficiently protected against dust, insect attacks, and harmful substances from outside. In the large film tunnels the residual

received: 04.06.2008
accepted: 28.07.2010

key words:
Packaging, plastic films, mechanical properties, permeation

oxygen concentration could be reduced to below 0.5% and a stabilization of relative humidity as well as good non-permeability of the packaging material could be achieved. The method of nitrogen-flushing to eliminate insect-pests could successfully be applied also to big and large numbers of objects. It turned out to be a cost-saving method of preserving museum objects, as it permits pest control directly at the museum or collection, without need for specialized equipment.



Figure 1. Carriages at the Wagenburg, Vienna.

1 Introduction

Museum objects require special attention concerning their conservation and preservation. In German-speaking countries approximately 11,000 museums and collections accommodate several hundred million objects. In Austria more than 90% of these objects are stored in special storage areas. Professional storage, storage equipment and pest control involve high costs, however. Climate fluctuation, attacks from pests (e.g. insects), air pollution or agglomeration of dust are typical causes of damage, which results in corrosion of metal parts or decomposition of organic material, which in turn may lead to brittleness of leather or velvet.

In a long-term research project of Kunsthistorisches Museum Wien (KHM), Essl Museum (Klosterneuburg, Austria), the Modesammlung Hetzendorf (fashion collection of Wien Museum), the Federal Office for the

Protection of Monuments, the Department for Conservation and Restoration of the University of Applied Arts Vienna and the Austrian Research Institute for Chemistry and Technology (*ofi*) Packaging Department, methods for packing, and thus of preserving, museum objects have been optimized.

The Museum of Carriages and Department of Court Uniforms (Wagenburg, Figure 1), a part of KHM, is an excellent example of the different kinds, sizes and quantities of exhibits that have to be packed. It holds more than 5,000 objects, such as carriages (101 court vehicles and 50 private vehicles of the gentry), pad blankets and harnesses. Other groups of objects covered by the project, such as large-sized contemporary paintings or jewellery made of copper and silver are part of the collections of the University of Applied Arts.

The method of packing art objects of all types in plastic film is widely used and cost-effective.¹⁻⁵ In the frame of this project this method of protecting objects in museum storage areas against pests and environmental influences was developed further. For the selection of the plastic films it is necessary to know the requirements of the packaging material (e.g. transparency, rigidity, seal qualities, etc.). This packaging method is often combined with the possibility of storing the objects in a protective gas atmosphere. On the one hand this helps killing insects and prevents further infestation, and on the other hand, it prevents oxidation reactions by excluding oxygen. In this project *ofi* identified the properties of plastic packaging materials – i.e. polyethylene (PE) films, PE-EVOH films and PET-SiOx-coated films – that are important for this kind of application and figured out which packaging conditions would be the best for the different museum items.

2 Materials and Methods

2.1 Materials

2.2.1 PE-EVOH

Composite film, folded, transparent, unprinted, film thickness 90 microns, Type Styria form BAR 90/6/0; manufacturer: Napiag, Zeltweg, Austria.

2.2.2 PET-SiOx

Composite film, transparent, unprinted, film thickness 104 microns, Dry Type Polyvel PET SiOx / PE 12-90 K; manufacturer: Wipf Austria, Marchtrenk, Austria

2.2.3 PE film

Transparent, unprinted, film thickness 104 microns; manufacturer: Napiag.

The material 2.1.1 was used for packaging carriages, sleighs and paintings, material 2.1.2 for copper and silver jewellery and the PE film (2.1.3) was used for tests with copper and silver jewellery as well as for pad blankets.

2.2 Methods

2.2.1 Long-term stability testing of films

For testing the long-term stability of barrier plastic films the PE-EVOH film (2.1.1) and the PET-SiOx-coated film (2.1.2) as well as sealed samples of both films were kept in the dark in an atmosphere of 100% oxygen and a temperature of 23 °C for a duration of 12 months. This corresponds to the use of these films for five years in dark storage areas under ambient atmospheres (20.9% oxygen, room temperature). The basis for this assumption is that for the degradation of plastics primarily oxidation processes are responsible and that an oxygen concentration five times higher than the atmospheric level would accelerate the oxidation processes by a factor of five, too (the influence of the factors light and temperature being excluded).

Before and after artificial ageing the elongation at break and the tensile strength of 5 samples of each barrier film (2.1.1 and 2.1.2) were tested according to ISO 527-3 with a Zwick type 1474 testing machine (Zwick, Ulm, Germany) at 50% RH and 23 °C. In addition, permeability to oxygen (double testing) was tested according to ASTM F 1927, with a Mocon Oxtran 2/20 module (supplied by Paul Lippke Handels GmbH, Neuwied, Germany) at 23 °C and 50% RH.

2.2.2 Permeability tests regarding air pollution

Different kinds of methods were used for packing museum objects, and a selection of different films was chosen. In particular, the problem of gas permeation through plastic films was addressed. To generate hermetically sealed packages it was essential to have precise knowledge of the permeation properties of the individual packaging materials to prevent the emission of chemical substances that could damage the exhibits, as well as to protect the conservator from toxic substances such as preservatives of the objects. Packed in special films, objects may be stored under less than optimal conditions, and may be released directly into the storage area. Therefore, the focus was placed on plastic films that have adequate barrier properties, and the permeability of the

plastic films to different typical air pollutions found in collection atmospheres was investigated.

The films of samples 2.1.1 to 2.1.3 were placed in measuring cells and stored at room temperature (21 °C). One side of the cell was exposed to the particular substances under study (acetic acid, formic acid, formaldehyde and sulphur dioxide). The other side was flushed with humid nitrogen (65% RH, approx. 2 ml/min). The substances permeating the films were flushed away by the nitrogen. They were collected on adsorption tubes and at certain intervals measured by means of gas chromatography/flame ionisation detection. The substances were identified on the basis of their retention times. Their quantitation was based on external calibration. Three specimens of each type of film were measured.

2.2.3 Storage of objects of art for protection against humidity

Pad blankets of the Wagenburg collection were stored in water vapour-tight PE film bags (2.1.3) in order to protect them against the massive seasonal changes in humidity, and the atmosphere within the bag was studied for 1.5 years and compared to the ambient atmosphere. For sensitive objects such as wooden carriages, textile structures, metal parts etc. a pronounced change in relative humidity can cause destructive damage. For example wood may show at high levels of humidity (> 65% RH) infestation of mildew, while at low levels of humidity (< 45% RH) stress cracks may appear on the surface of the wood.

2.2.4 Anoxic storage of art objects in plastic bags

For packing museum objects, bags of PE-EVOH film (2.1.1) or PET-SiOx film (2.1.2) filled with air or nitrogen were used. Indicators and reading devices were added to the plastic bags to control the internal climate within the bags. For creating the anoxic environment oxygen scavengers were either used as are, or after the bags had been flushed with nitrogen. The remaining very low concentration of oxygen (< 0.3%) was indicated with the aid of 'ageless eyes', an oxygen indicator whose colour changes from pink to blue if the residual oxygen content is 0.5% or more (supplier: Long Life for Art, Eichstetten, Germany). In addition, the gas atmospheres were regularly checked with a Dansensor, Checkmate 9900 oxygen/carbon dioxide tester (PBI-Dansensor, Ringsted, Denmark), by probing the interior of the plastic bags with a needle pierced through a septum

(Figure 2). A mobile electrode holder supported the heat sealing.



Figure 2. Checking the oxygen concentration within a package with a Dansensor oxygen/carbon dioxide tester.

In addition, it was also investigated by which test methods the condition of the plastic films can practically be controlled during the storage period. Therefore visual tightness checks and measurements of the oxygen concentration were performed continually. The close cooperation of *ofi* with the different museums gave the possibility of extensive testing before the actual implementation of packaging objects in plastic films.

2.2.4.1 Copper and silver jewellery

Jewellery made of copper and silver owned by the University of Applied Arts and stored in an office area had discoloured prior to the packaging experiments because of a reaction with sulphur compounds. To prevent such changes in the future, and as there was no possibility to improve the indoor atmosphere in this storage particular area, it was necessary to pack the objects into PE bags (2.1.3) and PET-SiOx (2.1.2) bags. Part of the PE bags were sealed and part was only folded, and oxygen was removed from the barrier material by means of oxygen absorbers (ATCO, FTM 2000 and 2000-s; supplier: Long Life for Art, Eichstetten, Germany) or nitrogen. The objects were stored for a total period of two years.

2.2.4.2 Elimination of harmful insects

Elimination of insects was a relevant aspect in the case of Wagenburg's carriages and sleighs from the Thurn und Taxis Marstall Museum of Regensburg (Germany) and paintings at Kremsmünster Abbey. For this purpose, the objects in question were stored in plastic films after elimination of oxygen for a period between 6 and 8 weeks, at a residual oxygen content of

<0.3% and a temperature of approx. 20 °C. In both cases, several objects were packed in tunnels of PE-EVOH film (2.1.1) that were several meters long, wide and high. The tunnels were flushed with nitrogen, the residual oxygen content was checked regularly and if needed (i.e. when increasing oxygen levels were observed) the tunnels were flushed again with nitrogen.

3 Results and Discussion

3.1 Long-term stability testing of films

Tables 1 and 2 show that the PE-EVOH film did not show any significant changes in the tested parameters. For the SiOx film an increase in the embrittlement of the sealed area by about 35%–45% and an increase in oxygen permeability by about 400% could be detected. Therefore, from the point of view of long-term stability PE-EVOH seems to be better suited as a barrier film for packing museum objects for long-term storage.

Before storage				
	F _{mean} [N/15 mm] longitudinal direction		F _{mean} [N/15 mm] lateral direction	
	Sample 2.1.1	Sample 2.1.2	Sample 2.1.1	Sample 2.1.2
\bar{x}	20.1+/-0.4	28.0+/-0.8	18.7+/-0.2	27.0+/-0.6
After storage				
	F _{mean} [N/15 mm] longitudinal direction		F _{mean} [N/15 mm] lateral direction	
	Sample 2.1.1	Sample 2.1.2	Sample 2.1.1	Sample 2.1.2
\bar{x}	18.6+/-1.4	37.6+/-2	20.6+/-0.3	39.6+/-1.9

Table 1: Mean value and standard deviations of sealed-seams' strengths of Samples 2.1.1 and 2.1.2.

Before storage		
	Oxygen permeability [cm ³ /m ² .d.bar]	
	Sample 2.1.1	Sample 2.1.2
\bar{x}	0.34	0.25
After accelerated storage at 23 °C		
	Oxygen permeability [cm ³ /m ² .d.bar]	
	Sample 2.1.1	Sample 2.1.2
\bar{x}	0.33	1.4

Table 2: Oxygen permeability of Samples 2.1.1 and 2.1.2.

3.2 Permeability tests regarding air pollutants

The permeation rate of the two barrier films 2.1.1 und 2.1.2 was below the respective detection limits of the method used with regard to all substances tested. Compared to PE film 2.1.3 these two barrier films showed a much higher resistance to pollutant permeation (barrier coefficient): around 19 times higher for acetic acid, more than

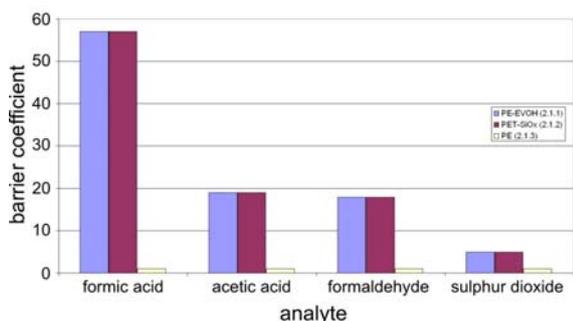


Figure 3. Barrier coefficients of several types of plastic film compared to PE-Film.

57 times higher for formic acid, more than 18 times higher for formaldehyde, and around 5 times higher for sulphur dioxide (Figure 3).

3.3 Storage of objects of art and protection against humidity

Figures 4 and 5 show the temperature and the relative humidity during packing tests at Wagenburg over a period of about 1.5 years. In the storage area strong seasonal variations predominate, with fluctuations in temperature from 3 °C to 29 °C. The relative humidity changes range from 39% to 63% RH.

Compared to the storage area, the humidity in a PE film bag (2.1.3) containing a pad blanket from Wagenburg is much more stable. Preferably it should constantly be around 50% RH, as this would be the best climate for preserving sensitive objects containing organic materials, such as leather, wood, textile fibres and horsehair.

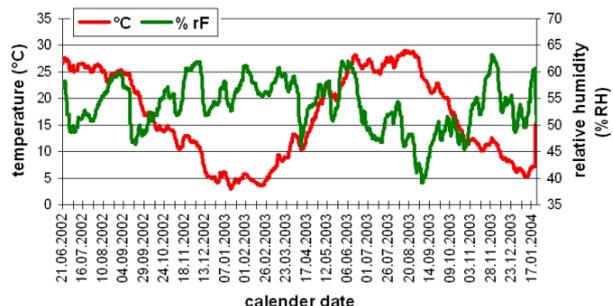


Figure 4. Temperature and relative humidity during storage.

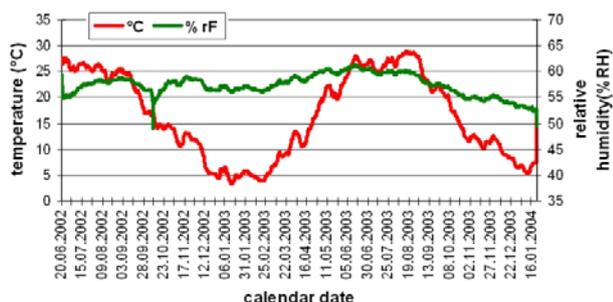


Figure 5. Temperature and relative humidity in a film bag, packed under unfavourable environmental conditions of 60% RH.

During the tests it turned out that the season of packaging, combined with the environmental conditions during packing (optimum 50% RH and 20-25 °C), is the most important factor for the relative humidity obtained within the enclosures. The use of preconditioned silica gel to reduce relative humidity within the enclosures is rather inefficient when the objects are packed into plastic bags at too high relative humidity. If an object is packed in summer with high temperature and RH values, significant amounts of water will desorb from the object surface into the atmosphere of the plastic bag enclosure. In winter the amount of water desorption will be much lower, which can result in a too dry atmosphere. During long storage especially at low temperatures a possible shifting of the dew point has also to be considered.

When storing objects in bags under anoxic conditions where the reduction of oxygen was achieved with oxygen absorbers it has to be considered that an increased amount of humidity absorber (like silica gel) has to be used for maintaining a constant relative humidity value since the oxygen absorber produces and releases water.

3.4 Anoxic storage of objects in plastic bags

3.4.1 Copper and silver jewellery

Unexpectedly, in the case of metal platelets *offi* obtained the best results when PE film (2.1.3) packs filled with air were used. The key to inhibit discoloration was not to reduce the concentration of oxygen but to decrease the access of sulphur-containing pollutants and to stabilize relative humidity. As an alternative to PE, use of a ceramic-coated film (SiOx-coated, 2.1.2) was also examined, but this method only involved higher costs and did not improve the results (Figure 6).



Figure 6. Silver jewellery in a film with heat seal

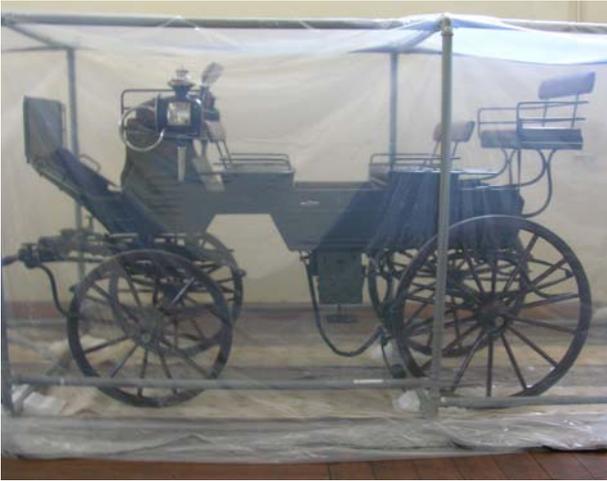


Figure 7. Carriages from the Thurn und Taxis Marstall Museum, Regensburg, in a film tunnel at the Wagenburg, Vienna.

3.4.2 Elimination of harming insects

The elimination of harming insects was successfully tested at the Wagenburg, on 17 carriages and sleighs (strongly infested by moths), coming from the Thurn und Taxis Marstall Museum of Regensburg (Germany), and at the Department for Conservation and Restoration of the University of Applied Arts, for paintings from Kremsmünster Abbey. The low oxygen atmosphere was kept within the tunnels (Figure 7) for a minimum of 8 weeks and the success of the treatment could be clearly shown by the vast number of dead moths as well as other insects in the tunnel. The costs of treatment were around 60% lower than those of treatment in an aeration plant in Vienna – especially because transport costs could be avoided in this way.

4 Conclusions

Taking everything into account one may say that all films chosen, i.e. PE, PE-EVOH and SiO_x-coated films, fulfil the corresponding requirements. An assessment of the objects that were stored during the project shows that packing them in plastic films provides sufficient protection against dust, insect attacks, and harmful substances from outside. In the large film tunnels the residual oxygen concentration could be reduced to below 0.5%. In addition, relative humidity could be stabilized and packaging material could be identified that exhibits low permeability to common indoor air pollutants.

In practice, it proved to be very difficult to control relative humidity inside the packing. Preconditioned silica gel turned out to be effective only partially. The environmental conditions during packing are more important than use of humidity

absorbers afterwards, therefore seasonal circumstances should be taken into account in the process of packaging.

In the case of anoxic packing it has to be pointed out that in the studies no advantages were detected compared to packaging under ambient conditions (air). In fact, a higher relative humidity was measured in the anoxic bags that caused a similar or more pronounced discoloration of cleaned objects compared to storage in air.

The method of nitrogen-flushing to eliminate insect pests was successfully applied also to big and large numbers of objects. It is a cost-saving method of preserving museum objects as it permits pest control directly at the museum or collection, without the need for specialized equipment.

5 Acknowledgements

The authors are indebted to the film-producing companies for supplying cost samples of different plastic films free of charge as well as to the Austrian Research Promotion Agency (FFG), Project Numbers 810020 and 813078, for financial support. We also thank the participating museums Kunsthistorisches Museum Wien (KHM), Essl Museum (Klosterneuburg, Austria), Wien Museum (Modesammlung Hetzendorf / fashion collection) and the Department for Conservation and Restoration of the University of Applied Arts Vienna.

6 References

1. J. Burke, *Anoxic Microenvironments: A Simple Guide*. SPNHC Leaflets (A Technical Publication Series of the Society for the Preservation of Natural History Collections) 1996, **1**, 1-4.
2. M. Gilberg, D. Grattan, *Oxygen-free Storage using Ageless Oxygen Absorber*, in: *Preventive Conservation – Practice, Theory and Research*. Preprints of the IIC Ottawa Congress, 12.-16. September 1994, IIC, Ottawa, 1994, 177-180.
3. M. Grießer, M. Kurzel-Runtscheiner, M. Novotny-Kargl, *Erfahrungen zur Verbesserung der Aufbewahrung historischer Objekte in nicht klimatisierten Museumsdepots durch Verpackung in Kunststoffolien unter kontrollierten Bedingungen*, *Technologische Studien. Kunsthistorisches Museum. Konservierung – Restaurierung – Forschung – Technologie*, 2005, **2**, 86-115.
4. P.B. Hatchfield, *Pollutants in the Museum Environment. Practical strategies for problem solving in design, exhibition and storage*, Archetype Publications, London, 2002.
5. C. Selwitz, S. Maekawa, *Inert Gases in the Control of Museum Insect Pests (research in conservation)*, The Getty Conservation Institute, Los Angeles, 1998.