July 1, 1992

27297

To be presented at the 2nd International Conference on Biodeterioration of Cultural Property, Oct. 5-8, 1992, Yokohama, Japan

# Practical application of nitrogen and argon fumigation procedures for insect control in museum objects.

Robert J. Koestler, The Metropolitan Museum of Art, New York, New York


## Abstract

Museums are moving away from the use of hazardous chemical treatments to control insect infestations in art objects. Chemical treatments often damage the art object and may pose a health risk to personnel handling the object after treatment. Alternative strategies being developed for museums include the use of nitrogen or argon gas as insect suffocants. Procedures being developed and tested at The Metropolitan Museum of Art using low-oxygen-permeable encasement systems and gas environments, including nitrogen and argon gases, are described.


## 1. Introduction

The need for an adequate means of controlling insect infestations within museum environments often emerges in a catastrophic fashion--when important objects are suddenly noted to be infested. It is at this point that deficiencies in control procedures are painfully apparent. Naturally, it is a bit late to test new treatments and, therefore, museum personnel responsible for preserving the collection must resort to the fastest expedient--usually application of a commercially available fumigant. In the past twenty-five years, in the U.S., a succession of insecticides have been employed and each, in turn, has been found to have been deleterious to the object and/or to personnel handling the object. These insecticides have included methyl bromide, ethylene oxide (e.g., Storey, 1985), and most recently, sulfuryl fluoride (Baker, et al., 1990).

In an attempt to be better prepared for the inevitable insect infestation in museum collections, research efforts by numerous individuals and organizations over the past few years have focused on alternate, generally non-chemical, treatments (for literature see Koestler and Vedral, 1991, or Art and

Archaeology Technical Abstracts). Treatments in this category, which can be termed environmental manipulation, have all attempted to control one or more of the essential environmental parameters necessary for insect pests to maintain themselves. Such environmental parameters include temperature, moisture, and atmosphere. The theory implicit in all these studies is that alteration of one, or preferably two or even all three of these parameters will put sufficient stress on the insect, at every stage of its life cycle, to cause the eradication of the pest. Equal to the goal of neutralizing the insect vector is the goal of not altering the form or substance of the art object to be saved.

Inevitably, it seems, the most effective means for pest control are also the ones most likely to cause an alteration in an art object. For example, using slightly higher temperatures than ambient is often an effective method of killing insects, yet this same temperature elevation may soften components of the art objects, causing them to flow and, even more important, increasing the rate of oxidation and dehydration of the objects. Freezing temperatures, on the other hand, while also an effective means of killing insects, may cause a variety of problems, ranging from the obvious--ice crystal formation--to the subtle--material fatigue from expansion and contraction caused by cooling and reheating, and brittleness due to the freezing, exacerbated by low-frequency vibrations from compressor units found in a freezer, or even from handling. (Background vibration "noise" has caused problems within the MMA's collection that have resulted in fragments of wooden objects completely detaching from the objects.)

Alteration of moisture conditions, generally toward a dryer condition, even if effective in killing insects, tends to be avoided within museums. Since many organic museum objects may crack if subjected to too dry a climate, museums usually attempt to stabilize exhibition and storage conditions at about 55% RH (Thomson, 1978).

The environmental manipulation that looks most benign, for an object, and yet will still be effective (albeit slowly) in killing insects, is the use of a low-oxygen atmosphere, specifically, the use of argon, nitrogen, or helium to flush out the existing oxygen level found in air (usually 20.8%).

The use of nitrogen for pest control is not new. Perhaps the earliest mention of its use was in the 1860's (see Bailey and Banks, 1980; Sigaut, 1980; and Annis, 1986). Since the 1960's many studies have been performed using nitrogen to control insect pests in grain storage silos, with notable success (e.g., Navarro, 1991; Navarro and Jay, 1987). Studies on the use of inert environments in the museum field have blossomed over the past five years (e.g., Gilberg, 1989, 1990, 1991; Koestler et al., in press; Valentin, 1990; Valentin and Preusser, 1990a,b).

The literature to date, and testing carried out at The Metropolitan Museum of Art (Koestler et al., in press, and unpublished) have encouraged the abandonment of chemical fumigation and the adoption of inert gas fumigation procedures at the MMA. Implementation of these procedures in a practical, day-to-day, museum situation is the focus of this paper.

## 2. Environmental Control Parameters

The aim of any suffocation treatment is to remove the oxygen without causing any deleterious (or too rapid) alteration in temperature, pressure, or humidity of the object to be treated.

### 2.1. Humidity

Gases useful in suffocating insects, e.g., nitrogen, argon, or helium, are available in pressurized cylinders. The moisture content of these cylinders is low, <10% RH. Direct application of unconditioned gas into a closed environment surrounding an object will cause a reduction in the humidity of the object, possibly resulting in cracking of the object. To avoid this, it is necessary to bubble the gas through a water (or water-glycerol) bath.

RH measurement of the conditioned gas is easily carried out by insertion of a hygrometer at the exit hose from the water bath. Experiments carried out at the MMA have shown that argon or nitrogen, when bubbled through water becomes conditioned to about 58% RH (at about 68°F [illegible] C) at a flow rate between 10 and 100 ml/min. Other levels may be achieved by mixing dry and conditioned gases (for RHs <58%) or by using glycerol and water mixtures (68% RH, highest level reported by Jay, et al., 1971).

## 2.2. Temperature

Ambient museum temperature is required for treating objects (about 68°F or 20°C). Equilibration of temperature from a gas cylinder to the ambient level is readily accomplished by a combination of the water conditioning method mentioned in section 2.1 and the use of long hose leads between the gas cylinder and the water container.

## 2.3. Pressure

Rapid pressure changes, either positive or negative, can be harmful to objects and are to be avoided. The pressure within a closed system can be easily monitored and regulated, with consideration given to the delicacy of the object within the environment. Regulation can be as simple as slicing open the bag envelope to permit more gas to escape, or more complex, i.e. by addition of an adjustable pressure relief value to a wall of the enclosure.

## 2.4. Length of treatment

Insect resistance to a low-oxygen environment varies considerably, not only from species to species, but also with life-cycle stage--egg, larval, pupal or adult--and with age within each cycle, among other factors (Jay, 1984; Navarro, 1991; Navarro and Jay, 1987). Low oxygen levels, in the range of 0.1%, achieved with nitrogen may produce 93-100% mortality rates in 14 days (at 26.7°C) for Tribolium spp, flour beetles, (Jay and Pearman, 1971) and in 21 days for Tineola bissilliella (Hummel), webbing clothes moth, Lasioderma serricorne (Frabicus), cigarette beetle, Stegobium paniceum (Linnaeus), drugstore beetle, and Anthrenus vorax (Linnaeus), carpet beetle, at 30°C (Gilberg, 1991). Higher temperatures generally produce higher mortality rates; lower humidity levels also produce higher mortality rates (Jay, et al., 1971).

Length of treatment in the MMA tests was patterned after Navarro (1991) in that the most conservative estimate of length of time was used for the most tolerant life stage of the most tolerant insect (so far tested). Navarro (1991) suggests Trogoderma granarium, kharpa beetle, as the most tolerant insect for grain storage problems, requiring 20 days to kill all stages. This insect is similar in tolerance to those reported in Gilberg (1991).

### 3. Examples of Enclosed Suffocation Systems

The series of procedures reported on here used nitrogen or argon (the majority of treatments were with argon), humidified to from 40 to 55% RH, depending on the object, and maintained at 0.1% $O_2$, or less, for 10 to 20 days. The use of argon instead of nitrogen may reduce the time of exposure needed for 100% mortality considerably, perhaps even by half (Valentin, personnel communication). The effectiveness of the procedure, while intended to be 100% based upon a survey of length-of-treatment studies in the literature, is unknown at present. The objects will be monitored for new insect activity periodically, and the effectiveness of the treatment tabulated for 1-2 years after treatment.

Insect infestations in the more than 50 objects treated included: Cryptotermes sp. (dry wood termite), Lyctus sp. (powder post beetle), and Attangenus sp. (black carpet beetle).

Development work is continuing on a variety of enclosed environment systems for suffocation. Descriptions of some follow.

#### 3.1. Tent-type enclosure

This technique utilized a large sheet of low-oxygen-permeable plastic to cover an object resting on a smooth, flat surface. The edges of the plastic were taped to the table surface. Holes were cut in two opposite corners. Humidified gas was flushed in one hole and allowed to push out the opposite hole. This technique was used at the MMA on a 16th century Andrea del Sarto panel painting that was infested with dry wood termites (Cryptotermes sp.). This type of enclosure was successful in that no further termite activity was discovered and no damage was caused by the treatment to the panel painting. However, the enclosure could not maintain the desired oxygen level without constant flushing. As a result, a large number of gas cylinders were required during the treatment (2-300 cu.ft. cylinders per day for at least 20 days).

### 3.2. Rigid-walled container system

A much improved treatment system was made from a heavy gauge polyethylene utility storage cart. A plexiglass cover was sealed to the top of the cart with a non-acetic-acid-containing silicone adhesive. Inlet and outlet fittings were drilled and threaded into the plexiglass. The humidified gas was then flushed into the chamber, and the outlet gas measured for $O_2$ levels. A level of about 50 ppm was achievable with the MMA system, and even though a small leak occurred (50 ppm/day), the system did not require constant flushing with new gas.

A disadvantage with this system is that the seal is not reusable. It has to be cleaned off and a new one applied for each use.

### 3.3. Mini-fumigation bubble

The mini-fumigation bubble system tried was a commercially available system (B&G Equipment Co., P.O. Box 130, Applebutter Lane, Plumsteadville, PA U.S.A. 18949-0130, licensed from Rentokil, Ltd, U.K.). This system utilizes a vacuum-type pump to pull the air out of the bubble. Then, new gas can either be pumped in with the motor, in the case of an insecticide, or pressure fed, in the case of inert gases. This system was originally designed for use with methyl bromide (a fumigant no longer recommended for use on museum material) and has been adapted for use with $CO_2$. (Carbon dioxide may, however, cause damage to an object due to the formation of carbonic acid. More research needs to be done before this gas is used on museum objects.) The advantages of this type of system lie in its potential for use with large objects, its portability, and its reusable seal. Unfortunately, the seal is the weakness in this system--it cannot maintain the low-oxygen internal environment for long periods of time (in our tests for more than a day).

### 3.4. Pouch or bag systems

The most successful system developed at the MMA so far, in terms of ease of bagging, sealing, and maintaining a low-oxygen environment, is the pouch or bag method. In this technique, the object is placed in a pouch made of heat-sealable low-oxygen permeable plastic (LLDPE, a linearly extruded polyethylene, 8 mils, from the Cryovac Div., W.R. Grace Co., Simpsonville, SC, U.S.A. $O_2$ permeability of 20-50 cc/day/$m^2$ at 20°C.) The oxygen environment inside the bag is flushed out with the humidified inert gas to the 0.1% $O_2$ level, an oxygen scavenger and oxygen indicator (Z-2000 AGELESS$^R$ and AGELESS EYE$^R$ indicator, respectively, Mitsubishi Gas Chemical America, Inc., 520 Madison Ave., New York, NY, U.S.A.--products available through Cryovac) are placed in the bag, and the bag is sealed. The oxygen scavenger functions to absorb any oxygen that diffuses out of the object or leaks into the bag. The $O_2$ indicator provides a quick passive monitoring method to ensure that $O_2$ levels within the bag are maintained at the desired level ($\leq$0.1%). Measurement with an oxygen meter is performed upon filling the bag, and periodically during the treatment. Measurements are taken from a top surface, as this is likely to have the highest oxygen level (since argon is heavier than oxygen). Measurement with an oxygen meter is highly recommended.

The pouch system is portable, inexpensive, quick to set up, effective, and reusable, provided the sides of the pouch have not been pierced.

## 4. CONCLUSIONS

The use of inert gases for suffocation of insect pests seems to be the safest method, for both art objects and humans, developed thus far for control of insect pests in museum environments. The gases currently undergoing testing at the MMA are argon and nitrogen. The long treatment time (20 days) can generally be accommodated within a museum context. Since implementation of inert gas insect control techniques at the MMA began, more than 50 art objects, representing a variety of materials, have been treated (in a 6-month period). The procedure appears to be safe for the objects (no deleterious effects have been seen on any test material or art object so far) and effective in killing insects (no insect activity has been found in any treated object, though the treated objects still do have to be monitored through a complete insect life cycle). The simplest, and most inexpensive and apparently effective system developed thus far is a low-oxygen-permeable polyethylene bag system.

**ACKNOWLEDGEMENTS**

I would like to thank Dr. A.E. Charola for advice during aspects of this work, Rudy Colban for invaluable assistance with mechanical aspects, Sarah Mc Gregor for day-to-day assistance with the actual work of treating objects, Mark Wypyski and Michele Marincola for reviewing the manuscript, and Vicki Riba Koestler for editing.

**REFERENCES**

Annis, P.C. Towards a rational controlled atmosphere dosage schedule: A review of current knowledge In: Proceedings of the 4th International Conference on Stored-Product Protection. Ed. E. Donahaye and S. Navarro. Permanent Committee of the International Conference on Stored Product Protection. Tel Aviv (1986) 128-148.

Art and Archaeology Technical Abstracts. IIC and The Getty Conservation Institute, 4503 Glencoe Avenue, Marina del Rey, CA 90292 USA.

Baker, M.T., H.D. Burgess, N.E. Binnie, M.R. Derrick, and J.R. Druzik. Laboratory investigation of the fumigant Vikane. ICOM Committee for Conservation. 9th Triennial Meeting Dresden, GDR, 26-31 August 1990. Preprints. Vol. II. ICOM. Paris (1990) 804-811.

Bailey, S.W., and H.J. Banks. A review of recent studies of the effects of controlled atmospheres on stored product pests. In: Controlled Atmospheres Storage of Grain. J. Shejbal (ed.) Elsevier. Amsterdam (1980) 101-118.

Gilberg, M. Inert atmosphere fumigation of museum objects. Studies in Conservation (1989) 3-4:80-84.

Gilberg, M. Inert atmospheres disinfestation using Ageless oxygen scavenger. ICOM Committee for Conservation. 9th Triennial Meeting Dresden, GDR, 26-31 August 1990. Preprints. Vol. II. Paris (1990) 812-816.

Gilberg, M. The effects of low oxygen atmospheres on museum pests. Studies in Conservation (1991) 36:93-98.

Jay, E. Imperfections in our current knowledge of insect biology as related to their response to controlled atmospheres. In: Proceedings International Sympposium on the Practical Aspects of Controlled Atmosphere and Fumigation in Grain Storages. E. Ripp el al. (eds.). Elsevier, Amsterdam. (1984) 493-508.

Jay, E.G., and G.C. Pearman, Jr. Susceptibility of two species of Tribolium (Coleoptera: Tenebrionidae) to alterations of atmospheric gas concentrations. J. Stored Prod. Res. (1971) 7:181-186.

Jay, E. G., R.T., Arbogast, and G.C. Pearman, Jr. Relative humidity: Its importance in the control of stored-product insects with modified atmospheric gas concentrations. J. Stored Prod. Res. (1971) 6:325-329.

Koestler, R.J., and J. Vedral. Biodeterioration of cultural property, a bibliography. In: Biodeterioration of Cultural Property. R.J. Koestler, (ed.) Elsevier Applied Sciences, London. (1991) 229-340.

Koestler, R.J., E. Parreira, E.D. Santoro, and P. Noble. The effect of selected biocides on easel painting material. Studies in Conservation. (in press).

Navarro, S. Application of modified atmospheres in the food industry. In: Kentucky Fumigation Workshop, Nov. 14-15, 1991. Christensen;s Urban Insect Solutions, Inc., 1420 Jandymar Ct., Lexington, KY 40517-3824. (1991) 26-31.

Navarro, S., and E.G. Jay. Application of modified atmospheres for controlling stored grain insects. 1987 BCPC Mono. No. 37 Stored Products Pest Control. USDA, ARS, Savannah, Georgia, U.S. (1987) 229-236.

Sigaut, F. Significance of underground storage in traditional systems of grain production In: Controlled Atmospheres Storage of Grain. J. Shejbal (ed.) Elsevier. Amsterdam (1980) 3-15.

Storey, K.O. Approaches to Pest Management in Musuems. Conservation Analytical Laboratory, Smithsonian Institutition, Suitland, MD 20746 U.S. (1985)

Thomson, G. The Museum Environment. The Butterworth Series on Conservation in the Arts, Archaeology, and Architecture. Butterworths, Boston. (1978).

Valentin, N. Insect eradication in museums and archives by oxygen replacement, a pilot project. ICOM. Committee for Conservation. 9th Triennial Meeting Dresden, GDR, 26-31 August 1990. Preprints. Vol. II. ICOM. Paris (1990) 821-823.

Valentin, N., and F. Preusser. Insect control by inert gases in museums, archives and libraries. Restaurator. (1990a) 11:22-33.

Valentin, N., and F. Preusser. Nitrogen for Biodeterioration Control on Museum Collections. In: Biodeterioration Research 3. G.C. Llewellyn and C.E. O'Rear (eds.) Plenum Press. New York (1990b) 511-523.