Treatment of Museum Collections for Pests

Preserving Our History

Conservators, collections managers, curators and pest management professionals alike face a difficult task when invaluable museum collections pieces have potential or active insect infestation. Inaction on the part of a curator can cause un-repairable damage to irreplaceable pieces.

Example of insect damage on a rug
(Photo courtesy of Insects Limited, Inc.)

Historically, fumigants or extreme poisons have been the norm for any museum pest problem. Even to this day, museum staffs have to be careful of contact with old taxidermy mounts and textiles due to a covering of arsenic and other poisons!
This practice was widely used during the 1800s and early 1900s. The most popular form of this insecticide was arsenical soap, but powders were also used. The soaps and powders were generally applied to the inside of the skin, and solutions were brushed onto the outside surface of infested specimens. Another procedure involved burying skins in sand saturated with arsenic or corrosive sublimate solutions ($HgCl_2$) for 12 – 24 hours. (Sirois 2001)

Arsenic use on textiles, on the other hand, was used in the dyeing process and generally not as an insecticidal treatment. For a period in time, this procedure was commonly used for dyeing with the colors indigo and green. The arsenic (sometimes mixed with human urine) made it possible to adhere these colors to fabrics that otherwise wouldn't accept the dye. It is important that museum personnel familiarize themselves with their artifacts and know of the potential for toxic poisons on individual pieces <u>before</u> handling.

For the past several years though, there has been a definite trend to stay away from any extreme poisons as well as conventional fumigants in pest situations. Museum personnel

have followed the trend of the general public and have adopted a more environmentally friendly philosophy over the last 30 – 40 years. The toxicity of poisons and the regulatory issues involved with the purchasing and use of fumigants can cause a casual user to actively search for a safer and more convenient method of eliminating pests. The storage of fumigants that are considered "Hazardous Materials" is generally not in the mindset of a conservator or curator. These "Hazardous Materials" must be documented and reported to government agencies for the purpose of emergency response issues. Also, in this world of post 9/11, the Department of Homeland Security wants to know where all hazardous materials are stored. They quite possibly will audit your facility to see if the fumigants are secured against terrorists getting there hands on them.
Disposal of spent fumigant or unused material can become a nightmare as well. I have assisted museums in the disposal of partial 55 gallon drums of liquid carbon tetrachloride, which is now a banned chemical. It literally costs the museum 1,000's of dollars to dispose of these drums at hazardous waste facilities. All of these issues take time and effort to work out. So, "What are the choices besides fumigants or extreme poisons?" Some options are discussed below.

Extreme Temperature:

Extreme temperatures offer a great means of insect control without the toxic aspect. Freezing is becoming commonplace in many of the larger museums and can be a viable and affordable option for smaller museums and historic houses. For the cost of a chest freezer (~$300.00) a conservator can rotate museum pieces through a freezing process and eliminate an existing insect infestation. This price is reasonable even with the tightest of budgets. Close attention to the physical make-up of your museum pieces has to be considered though. Many items will be damaged more from the freezing process, than from the insects themselves. Care should be taken to wrap the items in cloth before placing them in plastic bags to be frozen. This will help eliminate condensation damage. Some items that can be damaged from freezing are ivory, teeth, wax, film, stretched skins, oil or acrylic painting on canvas, antique glass, wood with dry or failing glue, inlays and veneers with damage, wood with cracks, composites made with these materials and water saturated materials. Items with high moisture content will expand and crack as they freeze. Veneers with damage will further the damage by expanding the crack. Stretched skins can literally shatter when frozen. Some paints will also fall off of the canvas they have been painted onto. Pieces with multiple components have to be examined closely. Hidden layers of non-conducive materials may be present.

Extreme heat can also be a means of achieving control. This is perhaps the most common means of pest control for museums in many third world countries in close proximity to the equator. By simply wrapping an item in black cloth, covering it in clear plastic and placing it in direct sunlight during the middle of the day, this procedure can rapidly kill all stages on insects. Think about how long you might survive with black cloth and plastic wrapped abound you and placed in the mid-day sun! This procedure works best in temperatures above 90 degrees F. We must again remember that museum pest management is the ultimate in "situational" pest management. Many items can be damaged beyond repair when exposed to extreme heat. These include objects with wax or resins, untanned or deteriorated leather or collagenus material and paintings. The relative humidity within the heated environment must be closely monitored to eliminate damage.

Condensation can occur on the shady side of the enclosure if no air flow method is incorporated (Strang 2001). Moisture loss can cause damage. There are important reasons we store museum pieces in controlled temperature and humidity environments. The temperatures from a heat treatment can degrade unstable or previously damaged materials. Don't do this form of treatment unless you're sure it won't harm your piece!

Table 1. **Fatal and Limiting Temperatures for Museum Pest Insects**

Species	Temperatures that limit breeding & development (°C)	Lethal Temperatures	
		Low temp (°C)	High temp. (°C)
Coleoptera: Anobiidae			
Anobium punctatum Powder Post Beetle	30	-16	48
Gastrallus sp.		-29	
Lasioderma serricorne Cigarette Beetle	16	-12	49
Stegobium paniceum Drugstore Beetle	17	-18	49
Coleoptera: Bostrychidae			
Rhyzopertha dominica Lesser Grain Borer	23	-1	
Coleoptera: Cerambycidae			
Hylotrupes bajulus Old House Borer			56
Coleoptera: Cucujidae			
Laemophloeus ferrugineus Rusty Grain Beetle	15	-6	
Oryzaephilus mercator Merchant Grain Beetle	15		
Oryzaephilus surinamensis Saw-Toothed Grain Beetle	17	-18	52
Coleoptera: Curculionidae			
Sitophilus granaries Granary Weevil	2	-18	54
Sitophilus oryzae Rice Weevil	5	-18	54
Coleoptera: Dermestidae			
Anthrenus flavipes Furniture Carpet Beetle		-14	Above 40
Anthrenus museorium Lesser Museum Beetle	4	Below -20	
Anthrenus scrophulariae Common Carpet Beetle	4		
Anthrenus verbasci Varied Carpet Beetle	14	-20	Above 40
Attagenus pellio		-18	52
Attagenus unicolor Black Carpet Beetle	10	-24	Above 41
Dermestes coarctatus			55
Dermestes lardarius Larder Beetle	15	Below -2	54
Dermestes maculates Hide Beetle	6	-23	60
Dermestes vorax		-15	
Reesa vespulae North American Yellow Jacket Beetle		-20	
Trogodema granarium Warehouse Beetle	15	-19	60
Trogoderma versicolor	20	Below -2	
Coleoptera: Lyctidae			

Lyctus africanus			54
Lyctus brunneus Brown Lyctus Beetle			58
Lyctus planicollis Southern Lyctus Beetle			55
Coleoptera: Ptinidae			
Ptinus tectus	10	Below -8	
Coleoptera: Tenebrionidae			
Tenebrio molitor Yellow Mealworm		-18	52
Tenebrio obscurus Dark Mealworm		-18	52
Tribolium castaneum Red Flour Beetle		-10	
Tribolium confusum Confused Flour Beetle	21	-20	54
Hymenoptera: Formicidae			
Camponotus herculeanus Northern Carpenter Ant		-29	
Camponotus obscuripes		-10	
Camponotus pennsylvanicus Black Carpenter Ant	0		
Isoptera: Kalotermitidae			
Cryptotermes brevis Powderpost Termite		-34	
Incisitermes minor Drywood Termite		-20	
Lepidoptera: Tineidae			
Tineola bisselliella Webbing Clothes Moth	9	-18	49
Lepidoptera: Pyralidae			
Anagasta kühniella Mediterranean Flour Moth	8	-18	
Ephestia elutella Tobacco Moth		-16	64
Plodia interpunctella Indianmeal Moth	18	-17	
Orthoptera: Blattellidae			
Blatella germanica German Cockroach			45
Orthoptera: Blattidae			
Blatta orientalis Oriental Cockroach	2	-8	46
Periplaneta americana American Cockroach		-15	45
Thysanura: Lepisimatidae			
Lepisma saccharina Silverfish	4		37
Thermobia domestica Firebrat	22	0	55

Strang, T.J.K., 1992. *A Review of Published Temperatures for the Control of Pest Insects in Museums*. Collection Forum, Vol. 8(2), 41-67

Deprivation (Anoxia):

Perhaps the least intrusive or damaging control tool at the disposal of museum personnel is the use of anoxia or oxygen deprivation. As long as your museum piece isn't a living organism, the absence of oxygen will kill all stages of pests while having no adverse effect on the piece. Before you jump up and down and scream," I've found the answer!", let it be known that removing the oxygen from an environment for the amount of time needed (approximately 2 weeks) to kill the eggs and larvae of certain species can be a difficult task. The expense of the oxygen absorbing sachets for large objects can be costly and the specialized oxygen barrier bags required to keep oxygen out are even more expensive. The cost really skyrockets as you get into larger pieces. A hand-held heat sealer is required to create the seal on the bags. There are several types of barrier films available to museum personnel. Most are them are multiple layer films consisting of an outer layer of polyester (Mylar) or polypropylene, a middle layer of aluminum and an inner layer of polyethylene. On a small scale, with small pieces, anoxia is an effective means of treatment.

Inert Gasses:

Inert gasses (Carbon dioxide and nitrogen) can also offer control with less restrictions than other fumigants. These "less toxic" applications are great tools to protect collections, but damage to artifacts and unsuccessful fumigations with inert gasses still occur quite frequently. The best way to perform a fumigation using CO_2 or nitrogen is within specialized chambers or fumigation bubbles designed specifically for these penetrative gasses. Although custom chambers can cost in the excess of $13,000 for a 500 cubic foot chamber, they can do a great job if they don't leak.

Custom Built Carbon Dioxide Fumigation Chamber
Photo courtesy of Melissa Owens

Most rooms used as fumigation chambers, cannot contain the high concentrations required for CO_2 or nitrogen, or cannot hold the concentration for the necessary 7 days. In an experimental CO_2 fumigation in an existing fumigation chamber at a Chicago museum, it became necessary to abort the fumigation less than 24 hours after beginning due to the fact that carbon dioxide levels in the adjacent areas reached un-safe levels. CO_2 is such an active gas molecule; it finds a way to escape from chambers that appear gas-tight. Even if safety is not an issue, if it becomes necessary to constantly add CO_2 or nitrogen throughout the fumigation, the availability of the bulky steel cylinders can make the fumigation logistically impossible. There is also some concern about the formation of carbonic acid when carbon dioxide encounters water during treatment. (Reichmuth 1986) On the flip side, smaller scale fumigations in vapor barrier bags can be successful and fairly easy to perform. The relative humidity must be closely watched in all CO_2 and nitrogen fumigations. These inert gasses tend to drastically lower the humidity in the area being fumigated. Humidifiers or a means of maintaining humidity must be determined before the fumigation begins. Now that we know these inert gasses work, we still have issues with government regulations. When being used as a pesticide, both CO_2 and nitrogen need to be registered as a pesticide in each state in which it is being used. The company BOC Gasses has registered CO_2 in only 35 states in the US, and nitrogen does not have any of these registrations. All aspects of each treatment must be considered.

See Table 2 for some basic facts about pest treatments and how they react with materials.

Table 2. **Some Treatments used in Museums and Their Effects on Materials**

Treatment	**Effects**
Dichlorvos (Vapona)(Baker et al 1990)	Dissolves waxes, lacquers and rubber. Corrodes metals at high humidity
Methyl Bromide (As of 2005 can only be used for export and quarantine)	Can cause a disagreeable odor with sulfur containing materials. Do not use with items containing hair, hide, feathers, fur, wool, latex or foam rubber, carbonless copy paper or cinder blocks.
Phosphine	Corrosive to copper and copper alloys. Also reacts with silver, nickel, gold and ultramarine
Sulfuryl Fluoride (Vikane)	Purest form of gas is un-reactive to most museum pieces. Trace by-products of the gas synthesis can cause tarnish to unprotected metals. Condensation from misapplication of the fumigant can also cause damage
Freezing	Can damage ivory, teeth, wax, film, stretched skins, oil or acrylic painting on canvas, antique glass, wood with dry or failing glue, inlays and veneers with damage, wood with cracks, composites made with these materials and water saturated materials
Heating	Not conducive with objects with wax or resins, untanned or deteriorated leather or collagenus material and paintings
Carbon Dioxide	Gas straight from a cylinder without humidification can cause desiccation and warping of moisture sensitive materials. Very difficult to contain the gas long enough to achieve an insect kill unless done in a specifically designed chamber or "bubble", some concern about the formation of carbonic acid.
Nitrogen	Gas straight from a cylinder without humidification can cause desiccation and warping of moisture sensitive materials. Very difficult to contain the gas long enough to achieve an insect kill unless done in a specifically designed chamber or "bubble" or on a small scale in vapor barrier bags.

Fumigants: Although conventional fumigants have gone by the wayside for many museums, there are still quite a few situations that clearly point to their use. If time is an issue, most fumigants will do the job in 1 – 3 days, where other forms of treatment can take 1 week to several months. The easiest way to have a fumigation performed is to have a knowledgeable firm that specializes in the fumigation of museum pieces do the work. They already have to perform all of the regulatory checks and know all of the safety issues. Let them store the chemicals and be subject to government audits instead of you. Note: It is important to verify their knowledge of museum pieces and get some references from others that they have done work for. If an artifact comes back damaged after being

fumigated, the conservator or curator will likely take the greatest criticism from administration. This is true even if they outsourced the job.
The three mainstream fumigants that are currently available to licensed applicators in the United States are methyl bromide, phosphine and sulfuryl fluoride. Fumigants work on the premise that any living and breathing pest in the fumigation environment will breathe in enough of the deadly gas to die. The gas is then expelled, leaving no residue. Much of the stored food in the world is fumigated before it is entered into the marketplace. This can only be done because of the nature of fumigants. They do their job with a vengeance, but then leave no trace behind them. All fumigants, if applied in the correct manner by trained personnel, will do an excellent job of killing all stages of insects deep within objects. For example, fumigation is an excellent choice for any dense wooden objects. The fumigant gas will travel down the paths that insects have burrowed out in the wood and kill them where they live, deep within the piece. A phosphine fumigation for large animal mounts can be the most efficient means of eliminating pests before they enter your museum.

Before and After Photos of Large Animal Mounts being Fumigated with Phosphine
(Courtesy Fumigation Service & Supply, Inc)

Sometimes, entire historic log cabins become infested with wood destroying organisms and fumigation is the only feasible means of eliminating these pests. We have seen entire historic cabins disassembled, brought in to be fumigated and then reassembled. Of course, with any treatment, it must be remembered that museum pest management is the ultimate in “situational” pest control. Every component of every piece of every group of collections must be studied to look for interaction with particular fumigants.
Methyl Bromide: Although this once popular fumigant had been widely used for many decades, methyl Bromide now (As of 2005) can only be used on quarantine and pre-shipment items for export in the US. In many European countries, it has been banned altogether. In the few areas that it still can be applied, methyl bromide works well on wood, metal or any electronic components with no known short or long term detrimental effects. Care must be taken not to direct the liquid or vapor directly onto objects as discoloration and a heavy residue of bromine salts will accumulate and cause damage. Do not use this fumigant with most ethnographic collections, as it will react with sulfur containing compounds and create a disagreeable odor. A large wool rug had to be removed from an office after a methyl bromide fumigation. The mal-odor from the rug

was too much for the office occupants to stand. Odor elimination efforts were unsuccessful.

Phosphine: This fumigant is the easiest to apply and will penetrate nicely into wood and ethnographic materials. Most metals are not the friends of phosphine though. Phosphine can be extremely corrosive to copper and copper alloys and will also react with silver, nickel and gold. Although many “wood only” furniture pieces can be safely fumigated with phosphine, many furniture pieces have brass or metal handles or metal decorations and should not be fumigated with phosphine unless these metal additions can be safely removed. Metallic based paints or pigments (e.g. ultramarine) in art paintings can be discolored by fumigating with phosphine.

Wicciamee being fumigated with Phosphine
(Courtesy Fumigation Service & Supply, Inc)

Sulfuryl Fluoride: Jim Druzik of the Getty Conservation Institute in Los Angeles, California called sulfuryl fluoride “the choirboy” of these three fumigants. It does not cause the disagreeable odors of methyl bromide and has nowhere near the corrosive effects of phosphine. Unfortunately, some extremely small (< .5%) components of the gas synthesis contain trace amounts of sulfur and hydrogen chloride. These trace amounts can cause acute tarnish of some unprotected metals during the fumigation process. No evidence of long-term acid reactions was found. If a process could be perfected to remove these trace sulfurs and chlorides, this would be the exclusive fumigant of choice for museum pieces. Druzik stated that even with the trace elements, sulfuryl fluoride has no adverse effects on paintings. It also is a great penetrator of wood products and ethnographic materials.

So, when you are faced with insect infestation and you need a viable treatment, study your collection carefully. Make sure that you select a treatment that will eliminate all stages of your insect pest. Most importantly, make sure that your treatment will preserve the integrity of the collection for years and years to come.

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