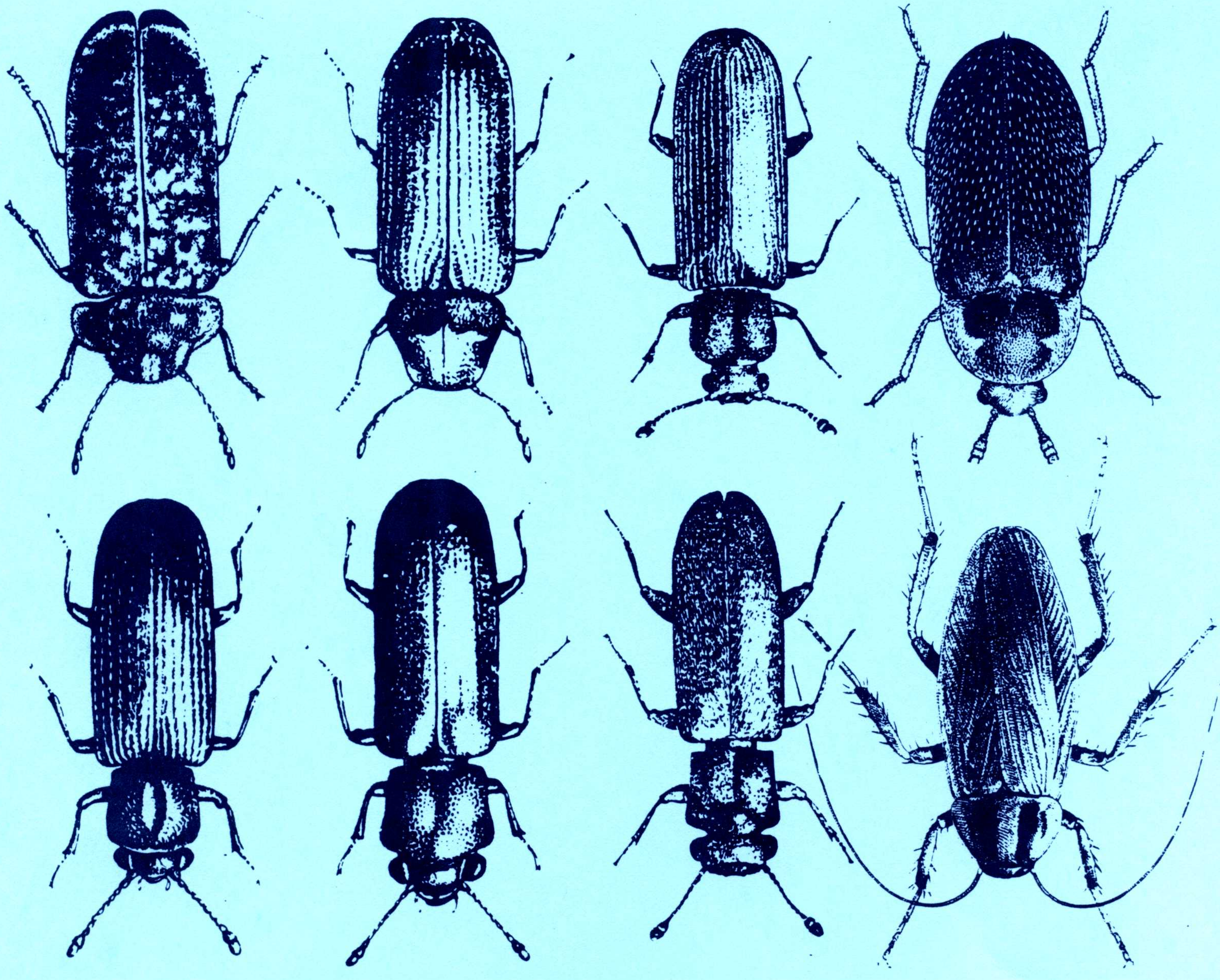

APPROACHES TO

Pest Management in Museums

by KEITH O. STORY

Conservation Analytical Laboratory, Smithsonian Institution

APPROACHES TO

PEST MANAGEMENT
IN
MUSEUMS

by

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TO

K. A. JOYSEY

For his inspired teaching and generous spirit.

P R E F A C E

This book is derived from a literature search and analysis project sponsored by the Conservation Analytical Laboratory of the Smithsonian Institution and conducted by Winchester Consultants in late 1984. The main purpose of the project was to expand the existing data base to aid planning of measures aimed at protecting susceptible museum collections from damage by insects.

In view of the growing (though often overstated) concern about the safety to humans of certain fumigants and other chemicals used to protect collections, a particular emphasis was placed on identifying possible non-chemical methods or methods involving low toxicity chemicals. Indeed, out of over 425 references given in this book, 335 references deal with methods other than solely using conventional pesticides. Though many of these methods are not yet proven, in terms of efficacy or safety to museum collections, they are referenced in this book to encourage more thought and research in the field of museum pest management.

In Part I of this book, the biology and damage potential of some key museum pests, together with possible countermeasures, are outlined. In Part II, which is the main part of the book, various approaches to museum pest management are reviewed, with particular regard to their efficacy and safety. An annotated bibliography is provided for each of these pest management approaches. These bibliographies are largely based on publications in fields unrelated to museums. This is partly purposeful, in order to bring new information to the museum fraternity. However, it also reflects the relative paucity of pest management data specific to museums.

Of the various pest management approaches described in this book, only one is applicable to all pest problems. This is the integrated pest management (IPM) approach, which is typically based on a combination of chemical and non-chemical methods. However, the particular combination must be customized to the situation, taking into account such factors as budgetary constraints, purposes and procedures for collections research and access, principles and ethics of conservation, occupational and public safety parameters and pest damage potential.

The author acknowledges Franzak and Foster, publishers of the Handbook of Pest Control, for their kind permission to use the illustrations in this book. Special thanks are due Ruth Gilbert for typing and proof reading the manuscript.

Keith Story, 1985.

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Continued over

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PART I

BIOLOGY AND OUTLINE CONTROL MEASURES FOR KEY INSECT PESTS OF MUSEUMS

INTRODUCTION

Any insect capable of entering a museum from the outdoor environment or introduced on materials carried from other buildings is capable of becoming a pest. This could include hundreds of different species, most of which may not normally be regarded as pests but which may pose a direct or indirect threat to collections. The most obvious direct threats are those arising from the feeding activities of insects, and almost any insect with biting mouthparts is capable of harming some items in museums. The pests described in Part I are all capable of causing such direct losses, and the feeding activities of some of them can devastate collections. In addition to feeding damage, collections may be marred by fecal deposits from flies, spiders, etc., as well as from the key pests described.

Indirect threats from insects are often overlooked, but in some cases they may be just as serious as feeding damage. For instance, a case is known where an insect caused a short circuit in a computer which in turn resulted in a fire which destroyed the computer and threatened the whole building. Another indirect threat arises when otherwise harmless insects die. Their bodies may then provide sustenance to key pests such as carpet beetles. In some cases large accumulations of dead insects, such as cluster flies, in hidden roof and wall voids become major reservoirs of such pests, ensuring constant reinvasion of collections unless measures are taken against these reservoirs. In other words, in addition to controlling the key pests, efforts must be aimed against all non-essential "inhabitants" of museums.

Part I deals with 12 key pest or pest groups. For each key pest, a description is given of its life cycle and general habits, as well as its feeding habits and its potential to damage museum collections. In addition, for each key pest, various control approaches are suggested. These approaches fall into the following four broad categories: cultural approaches (e.g. improved sanitation, temperature adjustment, etc.); mechanical approaches (e.g. sealing and screening pest entry points and harborages); trapping approaches (useful for control or for monitoring); and chemical approaches (e.g. residual insecticide sprays, baits). Promising areas for future research are indicated for each pest.

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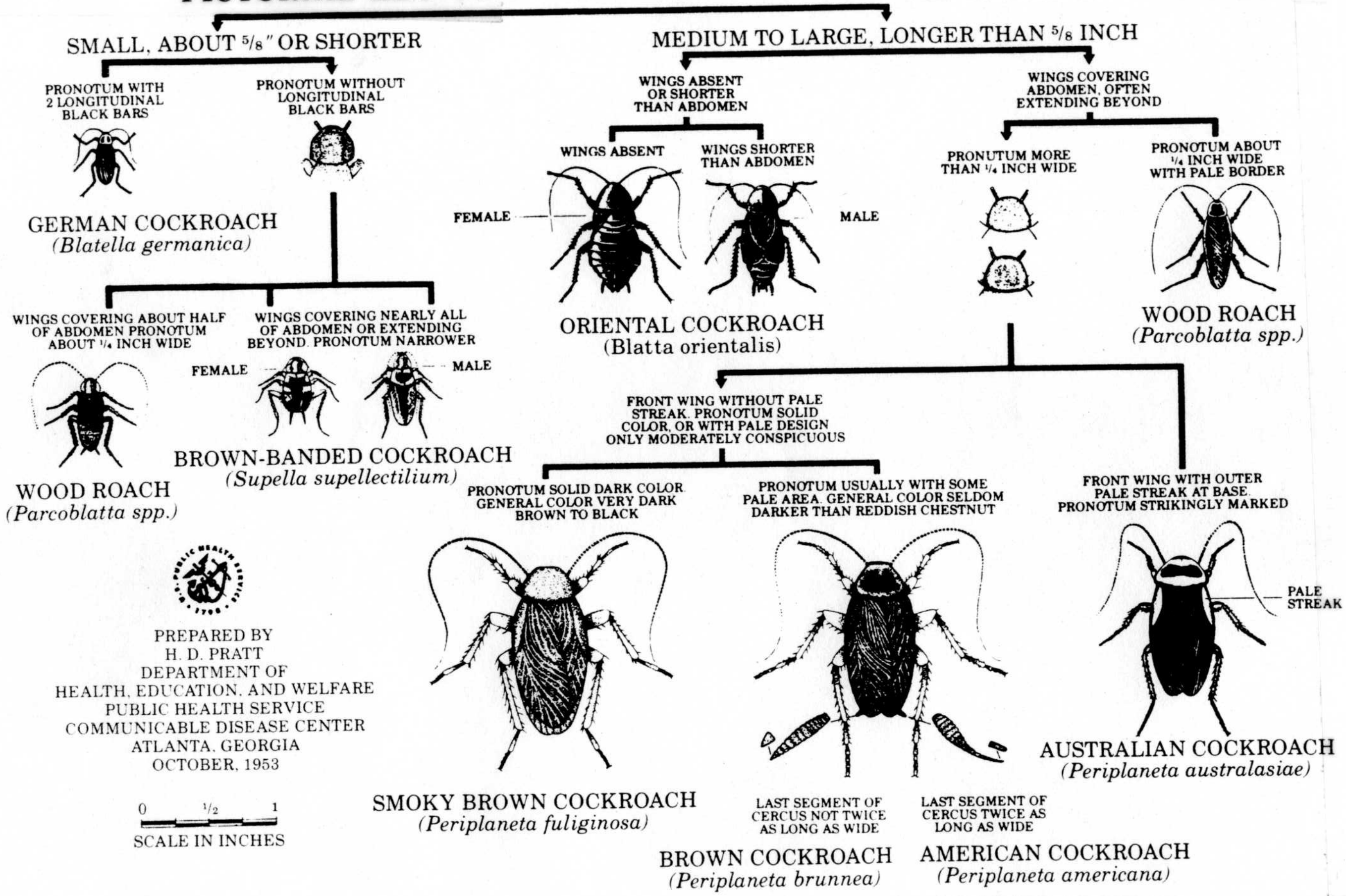
PICTORIAL KEY TO SOME COMMON ADULT COCKROACHES



PART I: SECTION 1

GERMAN COCKROACHES - *Blattella germanica*

A. Life Cycle and Habits

German cockroaches are the most common insect pests of buildings in the United States. Their success is due in part to their breeding faster and being more wary than other species. Moreover, their small size, compared to species such as the American and Oriental cockroaches, enables them to nest and hide in smaller crevices. In addition, German cockroaches produce an aggregation pheromone which accumulates on fecal material in preferred harborages and stimulates other German cockroaches to move to this location. Such aggregation provides increased feeding and breeding opportunities.

German cockroaches, like most species, are nocturnal. They spend about 75% of their time in dark, undisturbed crevices and voids close to food and water. They tend to be most common in kitchens and bathrooms because of their daily need of water and preference for warm areas.

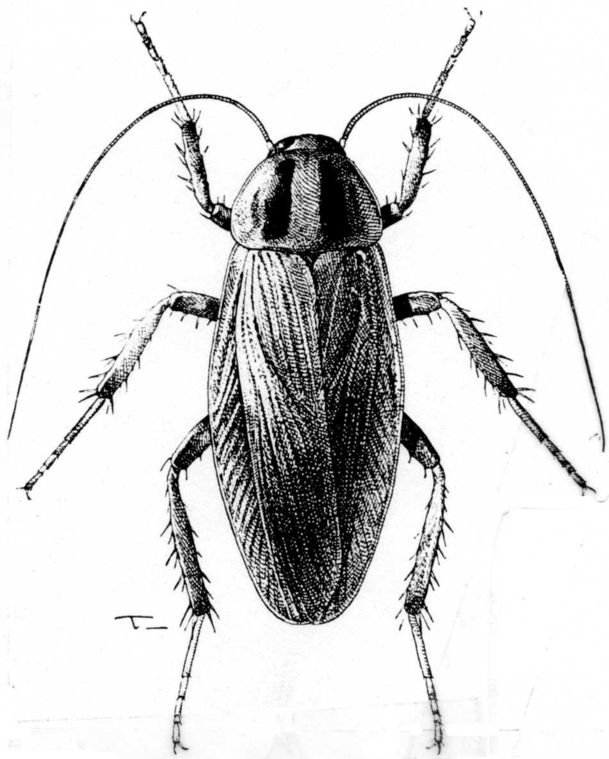
German cockroaches primarily inhabit buildings and cannot survive exposure outdoors in winter. In summer, building populations may spill over, resulting in cockroaches outdoors among accumulations of vegetation.

Breeding takes place throughout the year and eggs are laid in batches of 18 to 50 in capsules which are carried by the female until close to hatching time, in about 14 to 30 days. The emerging nymphs are immediately active and feed and live in the same area as adults. Nymphs molt six to seven times before becoming adults in about 60 days. The adults live about six months and in her life a female may produce four to eight egg capsules. Typically, at room temperature there are three to four generations a year.

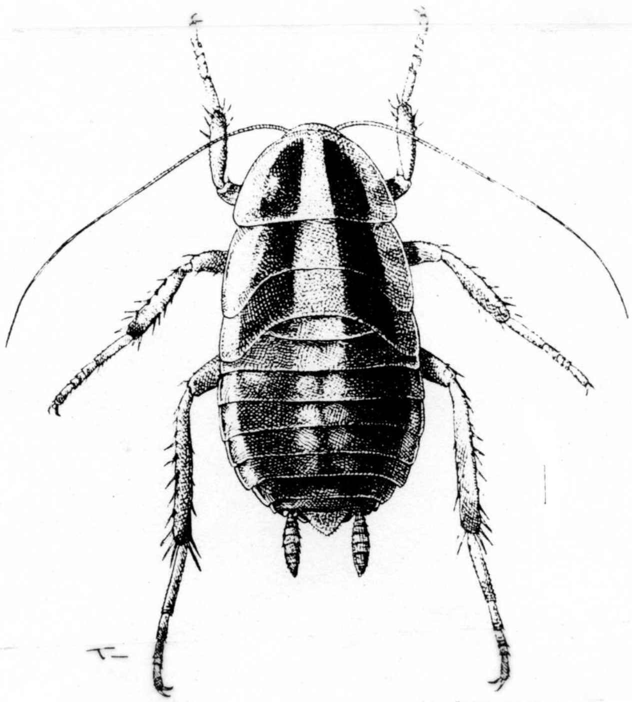
B. Feeding Habits and Damage Potential

German cockroaches and most other pest species of cockroaches are omnivorous. Moreover, being good climbers and being able to squeeze through narrow openings, they can gain access to a wide variety of materials. They are especially fond of starchy materials and meat products. In addition to human food they have been known to eat leather, hair, wallpaper, animal skins, dead insects and books. In addition to eating the pages of books and other papers, they feed on bindings, perhaps because of the glue. Materials soiled with sweat are especially favored. The damage caused by the chewing mouthparts includes holing and notching of edges.

In addition to chewing damage, cockroaches can cause severe staining as a result of vomiting, depositing feces and secreting fluid from abdominal glands. Indirect damage can result when cockroaches chew insulation on



Adult German cockroach. Body 10-15mm long. Two dark longitudinal streaks on the thorax are characteristic of this species.



Nymph of the German cockroach.

electrical wiring or in other ways interfere with electrical equipment. Major fires have been attributed to the activity of cockroaches.

C. Possible Control Measures

Cultural approaches:

1. Improved sanitation, particularly sealing food and garbage, cleaning drains and floors.

2. Minimizing exposed water by mending leaks and preventing condensation.

3. Check, and if necessary reject, incoming infested provisions.

4. Immediately unpack provisions and discard all cardboard boxes.

5. Remove wooden shelving, racks, etc. and replace with stainless steel (German cockroaches like wooden surfaces).

6. Ensure easy access behind or under equipment for inspection and cleaning.

7. Use plastic rather than paper labels on exhibits, storage containers, etc.

Mechanical approaches:

1. Minimize roach harborages (e.g. remove false ceilings, caulk crevices).

2. Seal vulnerable items in insect-proof containers.

3. Seal routes between rooms and between floors in multistorey buildings (e.g. plumbing and wiring conduits).

4. Install insect-proof power outlets.

5. Replace hollow doors with solid core doors.

Trapping approaches:

1. Electrical traps with or without attractants.

2. Sticky traps with or without attractants.

3. Jar traps (coated with grease or Teflon® on the inside rim to prevent escape) with or without attractants.

Chemical approaches:

1. Residual crack and crevice aerosol or water-based sprays based particularly on chlorpyrifos, bendiocarb, acephate or microencapsulated diazinon, aimed at cockroach harborages.

2. Residual spot or band sprays of residual insecticides aimed at intercepting cockroaches travelling between harborages and food sources.

3. Residual insecticide dusts, particularly boric acid, silica aerogel or bendiocarb dust, blown into voids harboring cockroaches (boric acid is particularly useful in pre-construction treatment of wall voids).

4. Insecticidal baits based on boric acid, propoxur or amidinohydrazone (particularly useful in non-food areas).

5. Building fumigation with sulfuryl fluoride (this technique is increasingly used for small buildings such as fast food franchises).

6. Aerosols or sprays of the insect growth regulator hydroprene (does not kill nymphs or adults but prevents new generation emerging).

D. Promising Areas for Research

- Combination of German cockroach aggregation pheromone with traps or insecticides.

- Cockroach repellents for use around vulnerable items.

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PART I: SECTION 2

HOUSE CRICKETS - *Acheta domesticus* (L.)

A. Life Cycle and Habits

House crickets can live outdoors in warm weather but commonly enter buildings with the onset of cooler weather. In infested warm buildings they can remain active throughout the year, but since they are nocturnal they are rarely seen.

Crickets lay eggs singly in crevices in dark places, including behind baseboards and in corners of rooms. They are reported to lay an average of 103 eggs at room temperature and over 700 eggs at 82°F. The eggs hatch after eight to 12 weeks. The emerging nymphs feed and grow, passing through seven to 11 molts in 9 to 33 weeks before becoming adult. The adults are aggressive feeders and live about two months, preferring to concentrate near warm areas such as steam pipes or fireplaces.

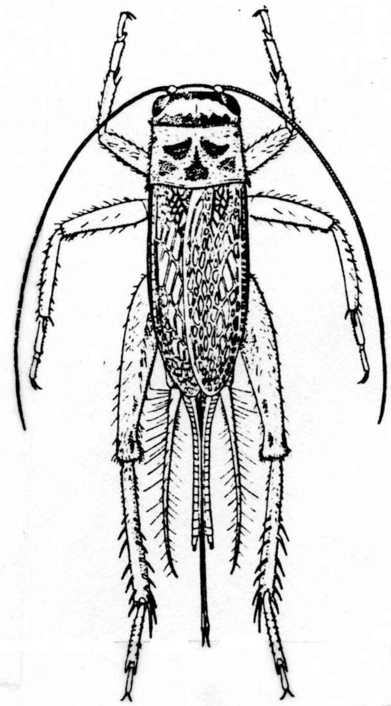
B. Feeding Habits and Damage Potential

House crickets are omnivorous, eating materials of animal and vegetable origin. They are both scavengers and predators, feeding on other insects as well as each other. Crickets have strong chewing mouthparts and they gnaw textiles of all types, but particularly thin fabrics. They are known to eat cotton, linen, wool, silk, furs and leather. Wood and paper are also gnawed. Items are most likely to be damaged if stained with sweat, grease, milk, syrup or other foods. Silk and woolens are especially susceptible to cricket attack. Items which provide no nutrition may also be damaged, including rayon, nylon, plastic sheeting and thin rubber goods. Crickets have also been known to burrow into the mortar of walls.

C. Possible Control Measures

Cultural approaches:

1. Removing stains from vulnerable items.
2. Creating a vegetation-free zone around the footings of buildings and keeping grass short.
3. Using exterior lighting which does not attract crickets at night.
4. Remove outside debris which may harbor crickets.



Female house cricket, *Acheta domesticus* (L.)
18-20mm long.

5. Clean indoor debris which might provide food or harborage.

6. Repair leaks, condensation problems, etc. which provide needed moisture for crickets.

Mechanical approaches:

1. Identify entry points from outside and seal them (e.g. caulk crevices, screen vents, install self-closing doors with sweeps, etc.).

2. Seal cracks and crevices indoors which may harbor crickets.

3. Seal vulnerable items in insect-proof containers.

Trapping approaches:

1. Use sticky traps, especially near doorways and other entry points.

2. Use of jar traps filled with liquid (crickets readily drown themselves in such traps).

Chemical approaches:

1. Apply outside perimeter sprays of appropriate residual insecticides, especially along footings and across doorways, loading bays, etc. (e.g. chlorpyrifos w.p., bendiocarb w.p.).

2. Apply spot sprays of residual insecticides to indoor structural surfaces frequented by crickets (e.g. bendiocarb wettable powder).

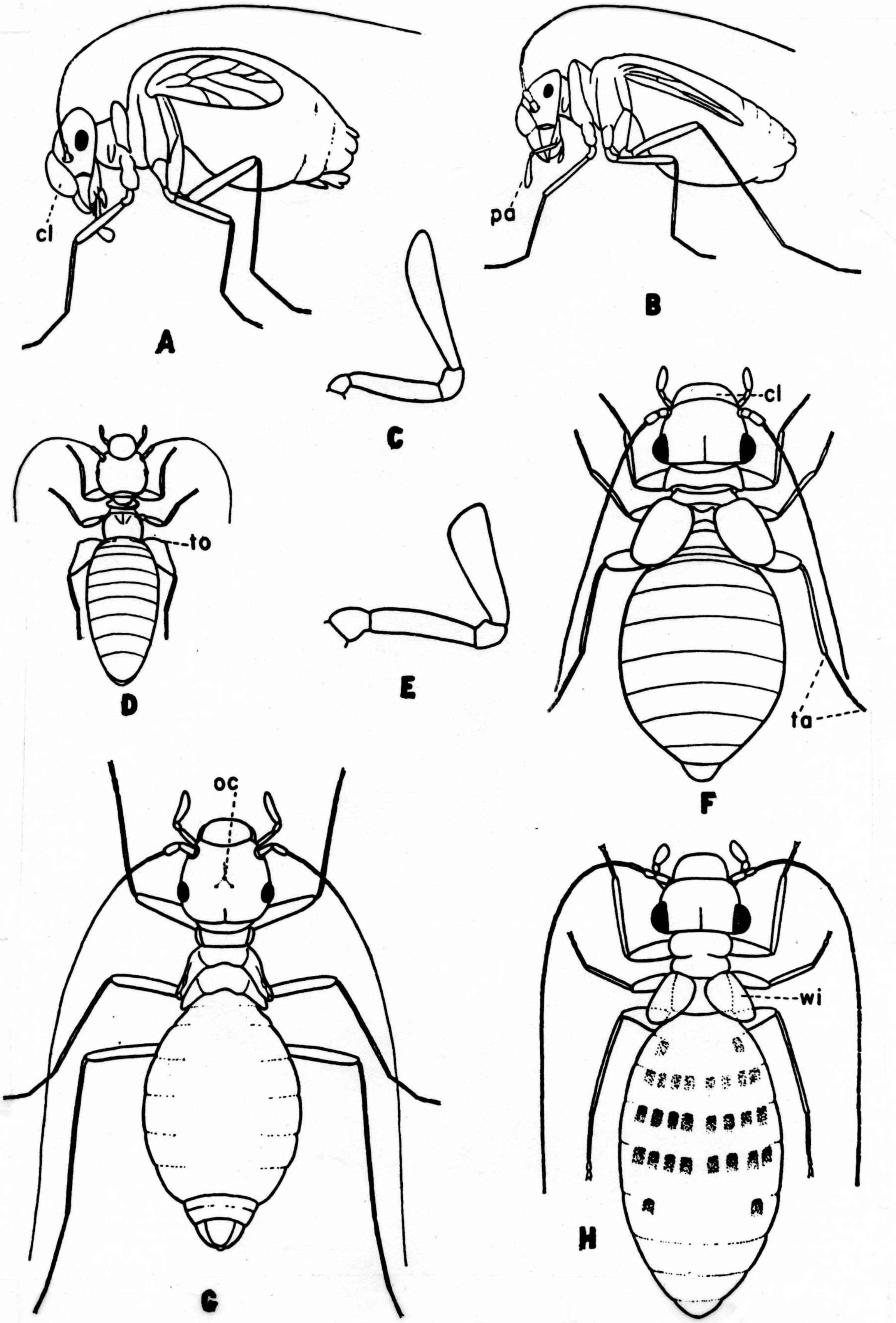
3. Inject residual aerosols, sprays or dusts into crevices occupied by crickets (e.g. silica aerogel or bendiocarb).

4. Use insecticide baits based on carbaryl, propoxur or chlorpyrifos.

D. Promising Areas for Research

- Use of sex pheromones to disrupt breeding.

--------------ooOoo--------------



Psocids. A - *Psocathropos;* B - *Dorypteryx;* C - Palpus of *Dorypteryx;* D - *Liposcelis;* E - Palpus of *Psocathropos;* F - *Lepinotus;* G - *Psyllipsocus;* H - *Trogium;* cl - sclerite on face; oc - ocelli; pa - palpus; ta - tarsus; to - femoral tooth; wi - wing.

PART I: SECTION 3

PSOCIDS OR BOOKLICE - *Liposcelis* spp.

A. Life Cycle and Habits

There are three life stages: egg, nymph and adult. Breeding takes place irregularly throughout the year and there may be six to eight generations a year. Reproduction is parthenogenic (i.e. females can reproduce without males) and the number of eggs laid ranges from less than 20 to over 90. The eggs hatch in six to 21 days. The emerging nymphs feed and grow, passing through four molts before becoming adult.

Booklice normally live outdoors in undisturbed situations and are commonly found on or under bark, dead leaves, damp wood and other damp areas rich in organic matter. The nymphs and adults die outdoors in cold winters and a new generation arises from overwintering eggs.

B. Feeding Habits and Damage Potential

Booklice, or psocids, feed primarily on microscopic molds growing in damp situations. They have no wings but are commonly carried into buildings on furniture, boxes, book and paper, etc., all of which may be supporting the growth of microscopic fungi, particularly if they have been kept in damp locations. Once introduced they can become very numerous in situations supporting mold growth. Typically they are most numerous in spring and summer and they may disappear in winter if artificial heating results in a very dry atmosphere not conducive to mold growth.

In addition to feeding on molds, there is some evidence they feed on pastes and glue of books and wallpaper. However, they do not appear to cause holing of paper as in the case of silverfish, beetles, cockroaches, etc. To some extent their presence is useful because they indicate the existence of conditions favoring molds and therefore deleterious to many collections. In addition to being found on paper they have been recorded in herbaria and insect collections but it is not known whether they caused damage. However, they certainly cause damage to stored foods such as cereals and other starchy items.

C. Possible Control Methods

Booklice or psocids are notoriously difficult to eliminate because they are so numerous outdoors and can frequently re-invade most buildings either actively or by being carried indoors on infested objects.

Cultural approaches:

1. Dehumidifying a building or a storage area will substantially reduce psocids.

2. Removing indoor reservoirs of psocids in damp objects, such as old cardboard boxes.

3. Storing items off concrete floors to prevent absorption of moisture leading to mold growth.

4. Removal of organic mulches (e.g. bark) adjacent to buildings.

5. Irradiating infested items.

6. Heating infested items (freezing may not kill the eggs).

7. Drying infested items.

Mechanical approaches:

1. Sealing vulnerable items in insect-proof containers.

Chemical approaches:

1. Use fungicide to kill molds supporting psocids. Formalin has been effective.

2. At present only pyrethrins are registered for psocid control but residual insecticide sprays such as chlorpyrifos, propoxur, propetamphos and bendiocarb are likely to be effective if applied in infested areas.

3. Residual insecticide dusts injected into infested wall voids, between floors and behind moldings are likely to be effective. Dessicant dusts, such as silica aerogel, and bendiocarb dust are labeled for such sites of application.

4. Residual dusts based on bendiocarb have been effective when applied to library shelves (personal experience).

5. Fumigation with naphthalene or paradichlorobenzene has been effective but HCN has often failed.

D. Promising Areas For Research

- Since mating is not required for reproduction there seems little potential for sex pheromones. The effectiveness of low toxicity dessicant dusts needs to be confirmed.

PART I: SECTION 4

SILVERFISH AND FIREBRATS

A. Life Cycles and Habits

Silverfish - *Lepisma saccharina* L.

The eggs of silverfish are laid singly or in two's or three's in crevices and under objects. On average, 100 eggs are laid by adults at 72°F to 80°F. They hatch in about 43 days at 72°F and 19 days at 90°F. The emerging nymphs grow and molt until they reach the reproductive stage in as little as three to four months or up to three years. Nymphs are killed by temperatures in excess of 98°F.

Adult silverfish alternately molt and lay eggs up to 50 times after reaching the adult stage. Most live about two years at temperatures of 84°F, but can live over three and one-half years at 72°F. Optimum conditions for development and reproduction are 72°F to 80°F and 75 to 97% relative humidity.

Note: Nymphs and adults avoid light.

Firebrat - *Thermobia domestica* (Pack.)

Females lay one to 195 eggs, with an average of 50, in crevices. Hatching nymphs mature in two to four months under optimum conditions. Temperatures below 32°F and above 112°F readily kill nymphs.

Adult firebrats molt throughout their life and may live one to two and one-half years at 90°to 98°F. A temperature range of 90° to 106°F is optimal.

Note: Nymphs and adults avoid light.

B. Feeding Habits and Damage Potential

Silverfish and firebrats have chewing mouthparts and eat both carbohydrate and protein-rich foods, including oats and dried beef. In museums and libraries they eat paper and fabrics. They remove sizing from paper in books, eat holes in paper (including etchings and prints), chew book bindings and feed on the glue and paste in bindings. They

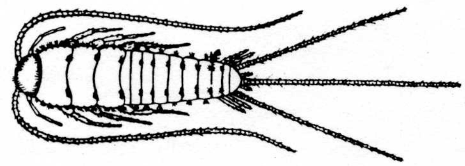
SILVERFISH
PICTORIAL KEY TO DOMESTIC SPECIES

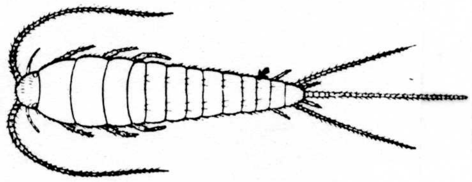
Chester J. Stojanovich and Harold George Scott

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
Communicable Disease Center
Atlanta, Georgia
1962

setae in tufts
color brown

setae single

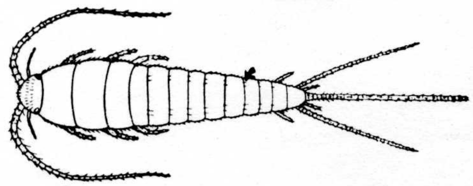


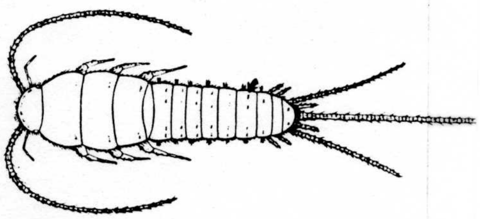


Thermobia domestica
FIREBRAT

without setal combs
color silver

with setal combs

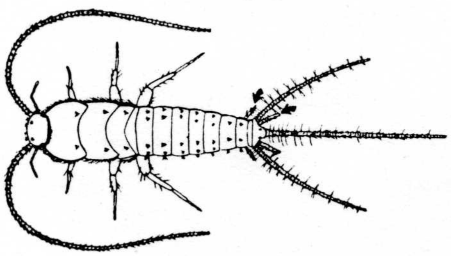




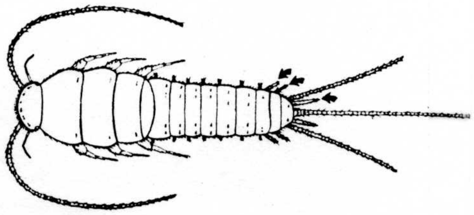
Lepisma saccharina
COMMON SILVERFISH

2 pairs of styli
color gray

3 pairs of styli
color brown



Ctenolepisma urbana
GIANT SILVERFISH
Ctenolepisma longicauda of some authors



Ctenolepisma quadriseriata
FOUR-LINED SILVERFISH

remove gold lettering to get at the paste beneath and attack labels and wallpaper to gain access to the glue. Fabric damage is characterised by irregular feeding on individual fibers, by occasional yellowish stains and by feces and scales left by the insects.

Silverfish are particularly fond of sizing in paper, including starch, dextrin, casein, gum and glue. Paper itself is eaten and highly refined chemical pulp papers are preferred over mechanical pulp paper. Firebrats do most damage to medium typewriter bond paper, regenerated cellulose and linen. Paper damage includes scraping, holing and "notching" of edges.

Both silverfish and firebrats prefer to feed on textiles of vegetable origin, including rayon, lisle and cotton but especially linen, and they seldom damage fibers of animal origin, such as wool or silk. However, in the absence of preferred papers or textiles, they may chew on any material, particularly if it is starched, sized or soiled.

Accumulations of crumbs, lint, etc. in crevices in moldings, baseboards and in carpets provide feeding opportunities for silverfish and firebrats. Neither insect needs liquid food but high humidity favors them.

Items which are in constant use are damaged little. But items which are undisturbed for long periods, particularly in dark, humid situations, are particularly vulnerable to attack by silverfish and firebrats.

The presence of silverfish and firebrats outdoors in nests of insects, birds and mammals, and under the bark of trees, provides high potential for building invasion. In addition, they can be easily introduced as eggs, nymphs or adults on items carried from another building.

C. Possible Control Measures

Cultural approaches:

1. Removal of food sources or pest reservoirs.
2. Reducing humidity (e.g. dehumidifying air, preventing plumbing leaks, condensation, etc.).
3. Increasing lighting in vulnerable areas to repel these insects.
4. Cooling infested items.
5. Irradiating infested items.
6. Heating infested items.

Mechanical approaches:

1. Caulk pest harborages.
2. Seal items vulnerable to attack in insect-proof containers.

Trapping approaches:

1. Sticky traps.

2. Jar traps (with or without bait).

Chemical approaches:

1. Surface sprays or crack and crevice injections of appropriate residual insecticides, especially bendiocarb.

2. Space sprays of appropriate non-residual insecticides, e.g. DDVP, pyrethrins or resmethrin.

3. Surface or crack and crevice application of insecticide dusts, especially bendiocarb, boric acid, silica aerogel or diatomaceous earth.

4. Insecticide baits (e.g. boric acid).

5. Repellents - none commercially available.

D. Promising Areas For Research

- Insecticide baits customized for silverfish and firebrats.

- Repellents.

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PART I: SECTION 5

HIDE OR LEATHER BEETLE - *Dermestes maculatus* (DeG.)

A. Life Cycle and Habits

Hide beetles are outdoor scavengers which frequently enter buildings by flying through windows and other openings or by being carried indoors on flowers. Once indoors they may be active throughout the year but are usually most abundant in spring and summer.

Eggs are laid singly or in batches of two to 20 in crevices and in food sources. A female may lay more than 800 eggs. The eggs hatch in two to 12 days. The larvae, which avoid light, are immediately active, feeding voraciously and molting up to 11 times under adverse conditions, but averaging seven molts. The larval period lasts about 30 days in warm conditions but over 200 days in cooler conditions. Four days prior to pupation the full grown larva leaves its food and can wander more than 30 feet seeking a place to pupate, often boring into hard materials such as wood, caulking, etc. for pupation. The non-feeding pupal stage lasts about 7 days.

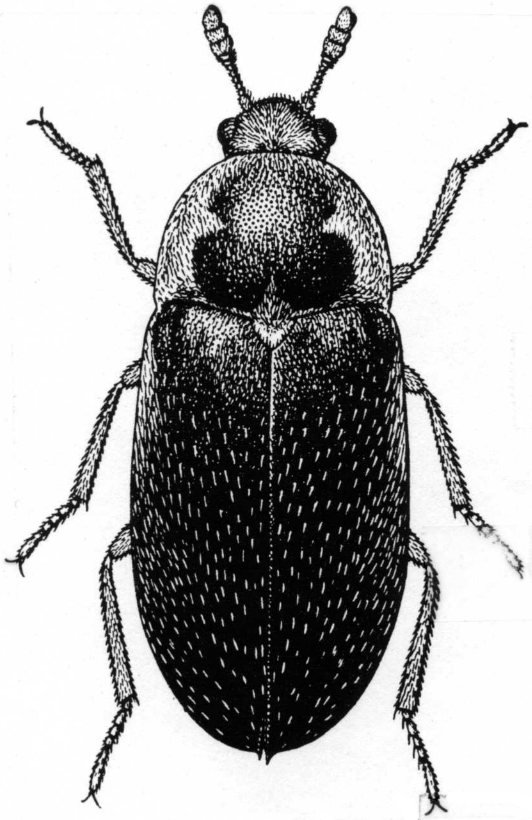
The adults feed on the same materials as the larvae. Within five days the adults are ready to mate and during this period and during egg laying they avoid the light. Later they seek light and are commonly found at windows. Adults live about 60 to 90 days.

B. Feeding Habits and Damage Potential

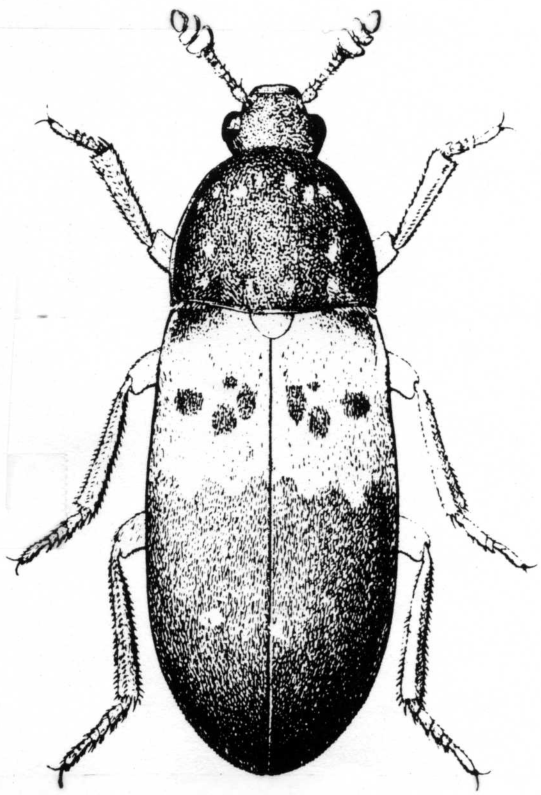
While both larvae and adults feed, most feeding and most damage is caused by the larvae. They prefer to feed on hides and skins but will also thrive on smoked meat and dried cheese. They are also known to feed on flowers and shrubs, particularly on flower heads. They commonly feed on dead insects both insect collections and accumulations of dead insects in attics, wall voids, etc.

The burrowing of full grown larvae when seeking a sheltered place to pupate can be very destructive. For instance, wooden beams can be completely honeycombed by successive generations of beetles. Larvae of the closely related larder beetle, D. lardarius, have been able to penetrate lead with ease, tin with some difficulty, but not aluminum or zinc. These beetles are also known to tunnel in upholstery.

Hide and related beetles are cannibalistic -the adults eat larvae and the larvae eat pupae!



Hide beetle, *Dermestes maculatus* (DeG.)
Body 5-10mm long.
Note the dark wing covers.



Larder beetle, *Dermestes lardarius* (L.)
Body 5-10mm long.
Note pale band across anterior portion of elytra.

C. Possible Control Measures

Cultural approaches:

1. Remove accumulations of dead insects from window sills, attics, catch trays of electric traps, etc., since these are a food source.

2. Remove bird nests, animal remains and other animal debris on or near the building since these directly or indirectly (via blowflies, etc.) provide food for hide beetles.

3. Reduce the earthworm population in surrounding lawns since these are hosts for cluster flies which enter buildings, die and provide nutrition for hide beetles.

4. Remove materials suitable for pupation, e.g. wood, styrofoam, etc. from vicinity of vulnerable items.

5. Physically remove larvae and adults from infested items.

6. Cool items to about 50°F to prevent feeding.

7. Freeze items to kill insects.

8. Heat infested items to kill insects.

9. Irradiate infested items.

Mechanical approaches:

1. Seal cracks and crevices near vulnerable items which may serve as oviposition or mating sites.

2. Seal vulnerable items in beetle-proof containers.

3. Seal routes by which beetles or future insect food of beetles (e.g. cluster flies) enter buildings.

Trapping approaches:

1. Use sticky traps in areas of beetle activity.

2. Electric light traps catch some adults but possibly after they have mated and laid eggs, and therefore too late.

Chemical approaches:

1. Surface sprays of residual insecticides applied to infested items or items vulnerable to attack and to adjacent surfaces, e.g. chlorpyrifos or bendiocarb.

2. Residual insecticide dusts blown into attics and other voids harboring hide beetles, e.g. bendiocarb dust (dessicant dusts have not been very effective).

3. Residual insecticide dusts brushed or combed through infested furs and skins (bendiocarb dust has been effective on mounted mammals). Irritant dusts such as silica aerogel should not be used where dusted items will be handled.

4. Fumigation with standard fumigants (e.g. sulfuryl fluoride) or atmospheric gases.

D. Promising Areas For Research

- Use of pheromone traps to prevent mating.

- Use of repellents on or around vulnerable items.

- Obtaining federal clearances for residual pyrethroids (e.g. permethrin or cypermethrin).

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PART I: SECTION 6

CARPET BEETLES I - *Anthrenus* spp.

A. Life Cycles and Habits

Varied carpet beetle - *Anthrenus verbasci* (L.)

This beetle is common outdoors where it is found on flowers (especially spiraea) and in the nests of birds and insects such as bees and wasps. Adults are most numerous outdoors in Washington, D.C. in late spring and summer. The adults are attracted to blue and white colors. They fly fairly high and enter buildings through windows and other openings, especially in late summer and fall. There is usually one generation a year indoors or outdoors, but poor diet or low temperatures may extend the life cycle to two years.

Females of the varied carpet beetle lay about 40 eggs in a lifetime and these hatch in 10 to 20 days at room temperature. The eggs may be laid on food or non-food items.

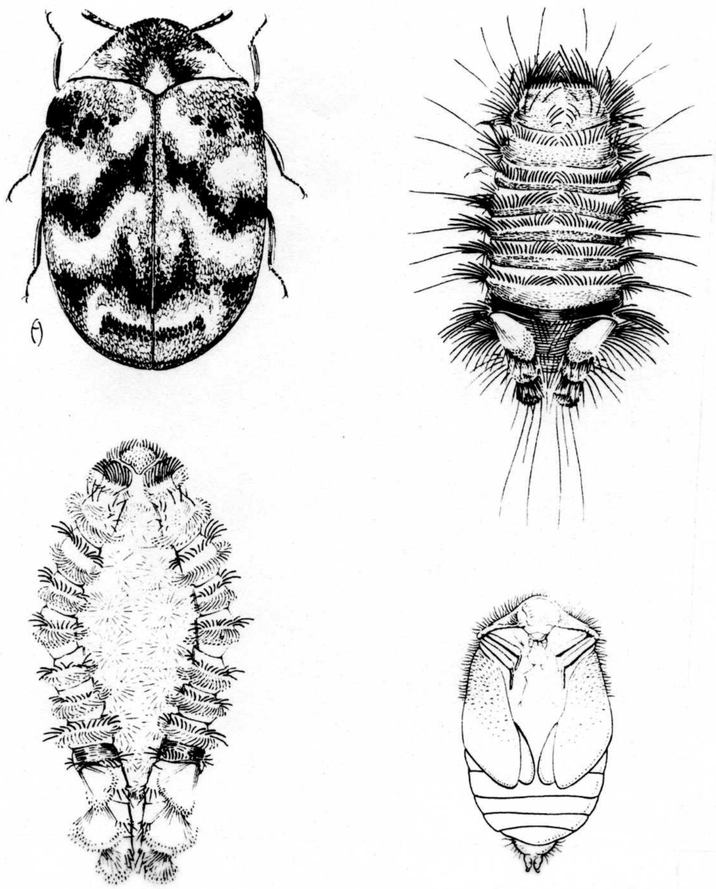
The hatching larvae feed almost immediately, avoiding light. There are five to 16 larval stages, with an average of about seven. The length of the larval life is usually 200 to 300 days, but over 600 days has been recorded. The larval stage is the overwintering stage outdoors.

Pupation takes place on the larval food, inside the last larval skin, and lasts 10 to 13 days. The resulting adults remain quiescent for a few days before emerging from the pupal (i.e. last larval) skin. At first, they avoid light but after laying most of their eggs they become attracted to light and are frequently found at windows en route to the outside. Males live 13 to 28 days and females 14 to 44 days.

Furniture carpet beetle - *A. flavipes* LeC. [= *vorax* (Waterh.)]

This beetle is primarily found indoors, and in heated buildings all stages are found throughout the year, but adults tend to be most common in summer. The length of the life cycle ranges from about 20 weeks to 14 months.

Female furniture carpet beetles lay 37 to 96 eggs in one to three batches, containing one to 57 eggs per batch. The eggs are laid on larval food such as the pile of carpets or on clothing. At room temperature the eggs hatch in nine to 21 days. The emerging larvae feed, grow and molt six to 12 times, over a period of 70 to 300 days



Varied carpet beetle, *Antrenus verbasci* (L.): Adult (2-3mm long), larva, pupal skin and pupa.

or more, before pupating in their last larval skin. The pupal stage lasts 14 to 19 days.

The adult life is divided into an initial quiescent stage, during which it rests in the last larval skin for six to 71 days at room temperatures, and an active stage which lasts about 60 days. The adult is the overwintering stage under cold conditions.

B. Feeding Habits and Damage Potential

While adults of both species feed with chewing mouthparts, it is the larval feeding that takes place over a longer period and is most destructive.

The varied carpet beetle has been recorded feeding on a great variety of animal and plant products indoors, including carpets, woolen garments, skins, furs, stuffed animals, leather book bindings, feathers, horns, whalebone, hair, silk, fish manure, dried silkworm pupae, cereals, and insect collections. Outdoors, the larvae often live as scavengers in nests of birds, bees, wasps and spiders. Adults have often been reported on flowers feeding on pollen.

The furniture carpet beetle is also primarily destructive of animal products and has been recorded feeding on wool, hair, fur, feathers, horn, leather, tortoise shell and silk. When cellulose materials such as linen, cotton, paper, rayon, jute and softwood are stained with animal matter, or when they enclose animal products, larvae will chew through them. They are also known to skeletonize dead mice, eat insects, dried cheese, old grain, casein, dried blood and the glue of book bindings.

C. Possible Control Measures

Cultural approaches:

1. Dry clean or wash infested textiles.

2. Vacuum lint from crevices, edges of carpets, etc. and dispose of vacuum bag.

3. Remove accumulations of dead insects from window sills, catch trays of light traps, etc.

4. Remove bird or rodent nests and remains of vertebrate pests from building and immediate surrounds.

5. Remove nests of wasps and bees and spider webs in or near building.

6. Physically remove carpet beetles from infested items and adjacent surfaces by vacuuming or brushing.

7. Prohibit cut flowers in building.

8. Cool items to about 50°F to prevent feeding.

9. Freeze items to kill insects.

10. Heat items to kill insects.

11. Irradiate items to kill insects.

12. Remove wool felts and replace with acrylic felt.

Mechanical approaches:

1. Seal vulnerable items in beetle resistant containers (e.g. plastic bags).

2. Seal routes of insect entry from outside.

Trapping approaches:

1. Use sticky traps in areas of beetle activity.

Chemical approaches:

1. Surface sprays of residual insecticides on infested items or adjacent surfaces, e.g. bendiocarb or chlorpyrifos.

2. Residual aerosols, sprays or dusts injected into shallow crevices harboring or capable of harboring carpet beetles.

3. Residual dusts blown into attics, wall voids and other voids vulnerable to infestation.

4. Residual insecticide dusts brushed or combed through skins and furs (e.g. bendiocarb dust).

5. Aerosol applications of pyrethrins to fabrics (N.B. resmethrin is currently labeled against webbing clothes moth and black carpet beetle).

6. Fumigation with standard fumigants (e.g. sulfuryl fluoride) or atmospheric gases. Also DDVP resin strips have been effective against the furniture carpet beetle.

D. Promising Areas For Research

- Use of pheromone traps. *Anthrenus* pheromones have been described but are not yet commercially available.

- Use of repellents on or around vulnerable items.

- Obtaining federal clearances for additional residual pyrethroids (especially resmethrin, permethrin or cypermethrin) for use against these species.

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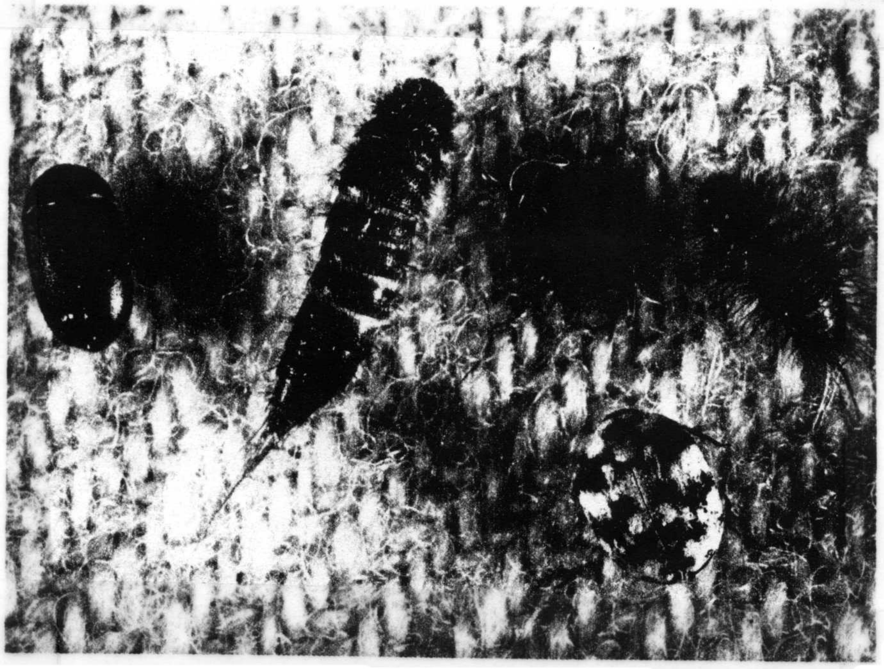
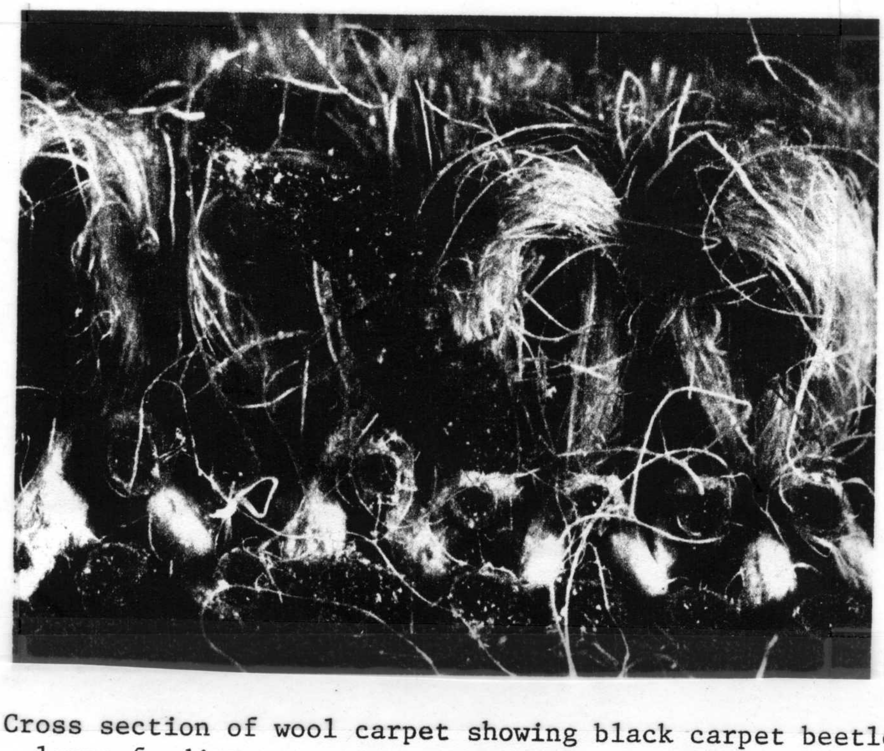


(left to right) Adult (3-5mm long) and larva of black carpet beetle, *Attagenus megatoma* (F.) and adult (2-4mm long) and larva of furniture carpet beetle, *Anthrenus flavipes* LeC.



Cross section of wool carpet showing black carpet beetle larva feeding.

PART I: SECTION 7

CARPET BEETLES II - *Attagenus megatoma* (F.) The black carpet beetle

A. Life Cycle and Habits

The black carpet beetle is reportedly the most widespread and destructive carpet beetle in the United States. It is found outdoors on flowers and scavenging in bird nests and on the remains of dead mammals and birds. They are thought to mostly enter buildings by flying, but are also brought indoors on flowers. The life cycle lasts from one to two years depending on temperature.

Sixty to 90 fragile eggs are laid in hidden locations such as in lint around baseboards, in hot air ducts and under furniture. They hatch in five to 16 days. The larvae feed actively and molt five to 11 times over a period of 258 to 639 days at room temperature. They avoid light. The larvae pupate in the last larval skin.

The pupal stage lasts six to 24 days (in Washington, D.C. pupation is mostly in the period April to June). The adults may remain in the pupal skin from two to 20 days before emerging and then may live about another 30 days. The adults do not avoid light, at least not all their life, and are found on window sills.

B. Feeding Habits and Potential Damage

The larvae of this beetle are a pest of many plant products, particularly seeds, grains and cereals, and are a major pest of animal products, being recorded on wool rugs and clothing, silk, felts, furs, skins, yarn, velvet, feathers, hair-filled mattresses, upholstered furniture, wool blankets, wool and hair house insulation, meat, insect meal, kid leather, milk powders, casein, books, birds nests and dead birds and mammals. The adults feed on pollen.

Apart from direct feeding damage, larval feeding may breach containers and make them vulnerable to insects which normally could not enter the container.

C. Possible Control Measures

Same as for Anthrenus spp but note the following:

- The eggs of black carpet beetles are very fragile and are more easily destroyed by brushing or vacuuming than the eggs of other carpet beetles or of clothes moths.

- Resmethrin is already labeled for use against black carpet beetles.

D. Promising Areas For Research

- Use of pheromone traps for monitoring.

- Use of pheromone traps for control.

N.B. *Attagenus megatoma* pheromones are commercially available and the reported earlier emergence of male beetles* would enable them to be pheromone-trapped before any females were available for mating. Mass trapping theoretically would break the life cycle and prevent a new generation appearing.

* Baker, J. E. 1977. Growth and development of the black carpet beetle on the laboratory diet. Ann. Entomol. Soc. Am 70(3): 296-98.

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PART I: SECTION 8

CLOTHES MOTHS

A. Life Cycles and Habits

Webbing clothes moth - *Tineola bisselliella* (Hummel)

The eggs are laid singly, or in groups of two or more, among the threads of cloth, fastened by a gelatinous material which prevents easy dislodgement. A total of 30 to 50 eggs are laid, with an average of 40 to 50, in a period of one day to three weeks. Eggs are laid as readily on cotton and silk as on wool. The eggs hatch in four to 21 days, averaging four to 10 days under warm conditions.

The emerging larvae are active and feed almost immediately. They often spin silk tubes or webbing, incorporating fragments of the infested medium and feces in its construction, as they move across the material. They molt five to 45 times, depending on the duration of the larval period, which ranges from 40 days to over two years. The final stage larvae spin a silk web in which they pupate.

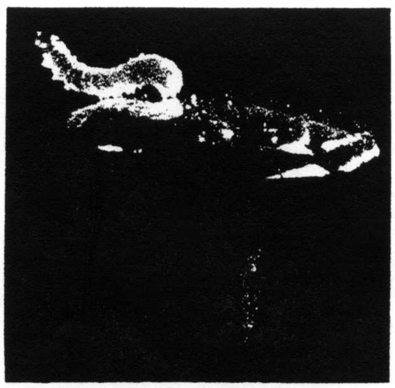
The pupation period ranges from eight to 44 days, being least at higher temperatures. The adults emerge throughout the year in heated buildings. The males are reported to be attracted to females by a scent (pheromone) released from the female's abdomen. The adults have non-functional mouthparts and therefore do not feed. They live up to four weeks but are rarely seen because they avoid light.

Casemaking clothes moth - *Tinea pellionella* (Linnaeus)

This species has a similar life cycle and habits to the webbing clothes moth, except for the following key differences. The larvae spin a case of silk and interweave in it some of the fibers on which they are feeding. When the larva moves it drags the case with it and it will die if removed from the case. Unlike the webbing clothes moth, the casemaking clothes moth rarely spins a web on the material it is eating.

When the larva is ready to pupate, it often leaves its food source and seeks pupation crevices on walls or ceilings. As in other species, pupation takes place within the larval skin.

Adults of webbing clothes moth, *Tineola bisselliella* (Hum.). Note absence of dark wing markings. Length 6-8mm.



Newly emerged larva of webbing clothes moth on a pin head.

B. Feeding Habits and Damage Potential

The webbing clothes moth is the most common moth causing damage to textiles but the casemaking clothes moth and rarer species such as the tapestry moth (Trichophaga tapetzella) also damage textiles. Damage is done by the larvae as they feed with their chewing mouthparts. Larvae (at least of the webbing clothes moth) cannot complete their development on clean woolen fabrics and this may explain their preference for stained areas, perhaps because of a need for Vitamin B or salts which are found in sweat, urine, etc.

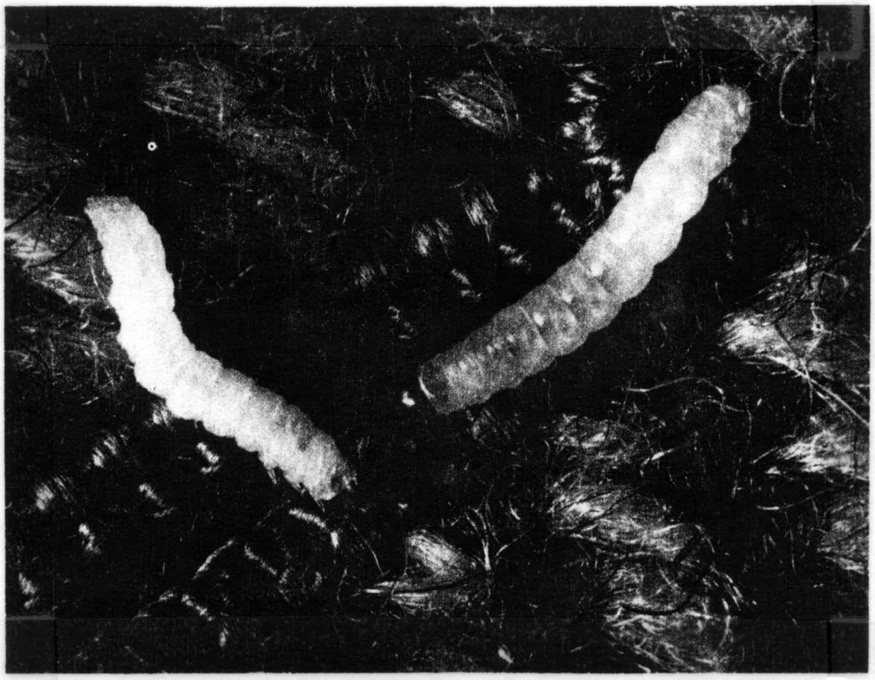
Clothes moths have been reported to feed on the following: furs, uncleaned skeletons, bird skins, insect specimens, raw wool, beef meal, fish meal, casein, milk products, fingernail clippings, animal-bristle brushes, carpets, woolen clothes, blankets, upholstery, stored yarn, piano felts, felts in display cases, hair filling of chairs and lint accumulations.

Clothes moth larvae do not digest vegetable products but as a result of "exploratory feeding" or when vegetable fibers are coated with sizing or other attractants, they can damage silk, cotton, linen, and even paper. In these cases, as with animal fiber products, holes are eaten in the material. In fabrics made of mixtures of wool and synthetics, the synthetic fibers are also chewed, including nylon, Dynel, Dacron, Orlon, rayon, etc. These synthetics pass unchanged through the larval gut. In severe infestations, dead moths and larvae can be an important food source.

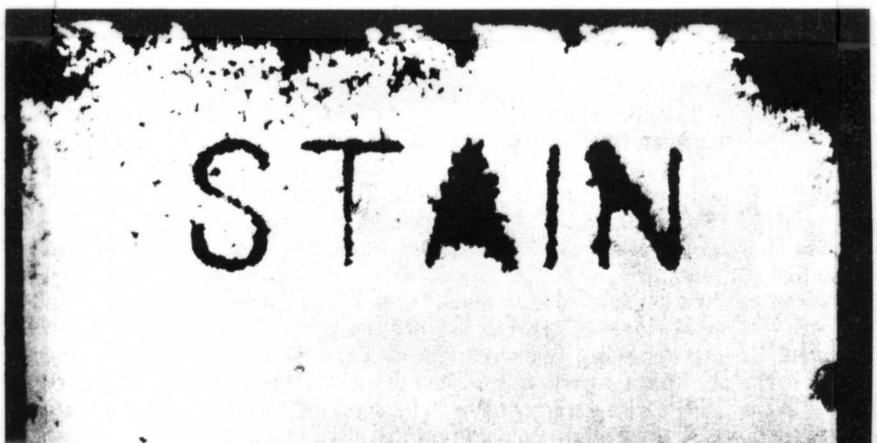
C. Possible Control Measures

Cultural approaches:

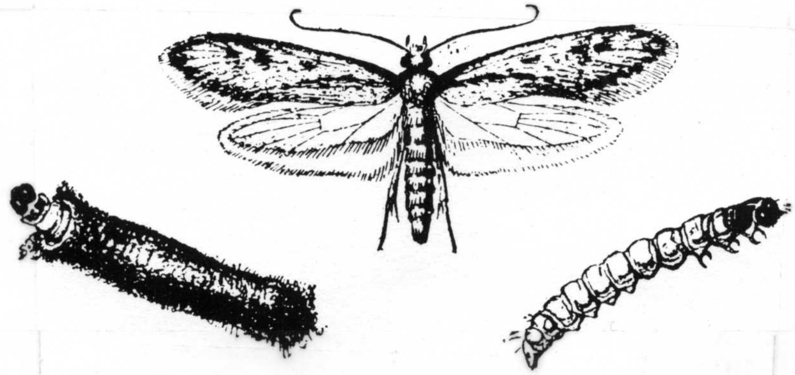
1. Thorough vacuum cleaning to remove lint and some of the pests from floors, air ducts.
2. Dry cleaning fabrics to remove nutritious stains and to kill larvae and eggs.
3. Removal of rodent and bird nests.
4. Brushing or combing fabrics and furs.
5. Using lighting to repel adult moths from vulnerable items.
6. Cooling items to about 50°F to prevent feeding.
7. Freezing items to kill insects.
8. Irradiating infested items.
9. Heating infested items.
10. Remove wool felts and replace with acrylic felts.



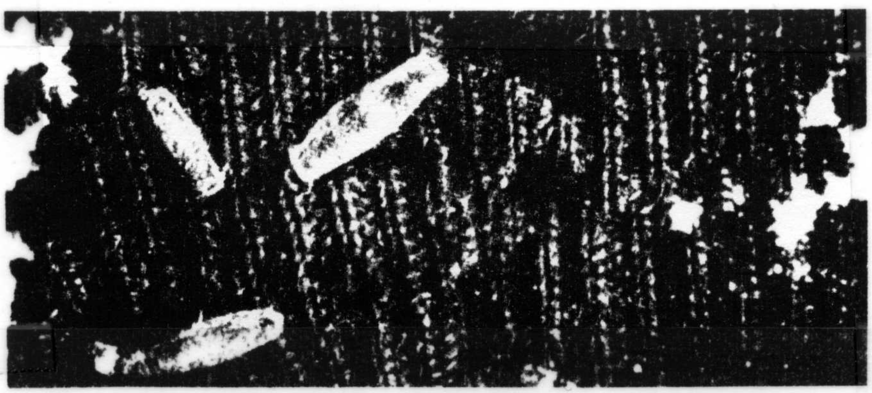
Larvae of webbing clothes moth on a buttonhole.



Larvae of webbing clothes moths are attracted to stains. The word "STAIN" was treated with tomato juice and exposed to larvae.



Adult, larvae and case of casemaking clothes moth, *Tinea pellionella* (L.)
Wing expanse is 10-14mm.



Cases (6-9mm long) of the casemaking clothes moth.

Tapestry or carpet moth, *Trichophaga tapetzella* (L.)
Wing expanse is 16-22mm.

Mechanical approaches:

1. Seal items vulnerable to attack in insect-proof containers.

2. Caulk crevices to reduce lint accumulations and pupation sites for casemaking clothes moth.

Trapping approaches:

1. Put sticky traps baited with animal substances in dark places to attract adults and larvae.

2. Use box traps containing cloth baited with fish meal, etc.

Chemical approaches:

1. Surface sprays of residual insecticides applied to infested items or items vulnerable to attack or adjacent surfaces, e.g. permethrin, bendiocarb, resmethrin.

2. Space sprays of non-residual insecticides, e.g. pyrethrins, DDVP.

3. Use vinyl strips impregnated with DDVP for enclosed storage containers.

4. Fumigation with standard fumigants or atmospheric gases.

5. Brush residual insecticide dust into fur, feathers, etc., e.g. bendiocarb.

6. Aerosol applications of resmethrin to fabrics.

D. Promising Areas For Research

- Use of pheromones to attract male moths to traps and prevent breeding.

- Use of repellents on or around vulnerable items.

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PART I: SECTION 9

FURNITURE BEETLE - *Anobium punctatum* (DeG.)

A. Life Cycle and Habits

This species, and other wood infesting anobiids, occur outdoors in old dry limbs where they normally complete their life cycle in one year. Indoors they infest structural timbers and furniture and when the moisture content is low the life cycle takes two or more years, so there may be several generations at the same time in one piece of wood. They are brought into buildings on firewood, packing cases, wooden yard furniture and antique furniture.

Females lay eggs singly or in small groups in crevices or exit holes in wood. Unfinished rough wood is preferred and eggs are not usually laid on painted or varnished wood. Up to 54 eggs have been recorded laid by one female. They hatch in six to 10 days. The larvae chew the wood, creating tunnels and producing frass made up mostly of small oval pellets (the appearance of piles of frass beneath exit holes is an important clue to infestation). After one or more years of growth the larva tunnels towards the surface of the wood and creates a pupal chamber just below the surface. Pupation lasts two to three weeks.

The adults chew their way from the pupal cell to the surface of the wood and emerge by chewing a round exit hole about 2 mm. in diameter (it varies with the size of the individual beetle). The adults begin mating on the surface of the wood soon after emergence but may retreat into holes or crevices to complete mating.

B. Feeding Habits and Damage Potential

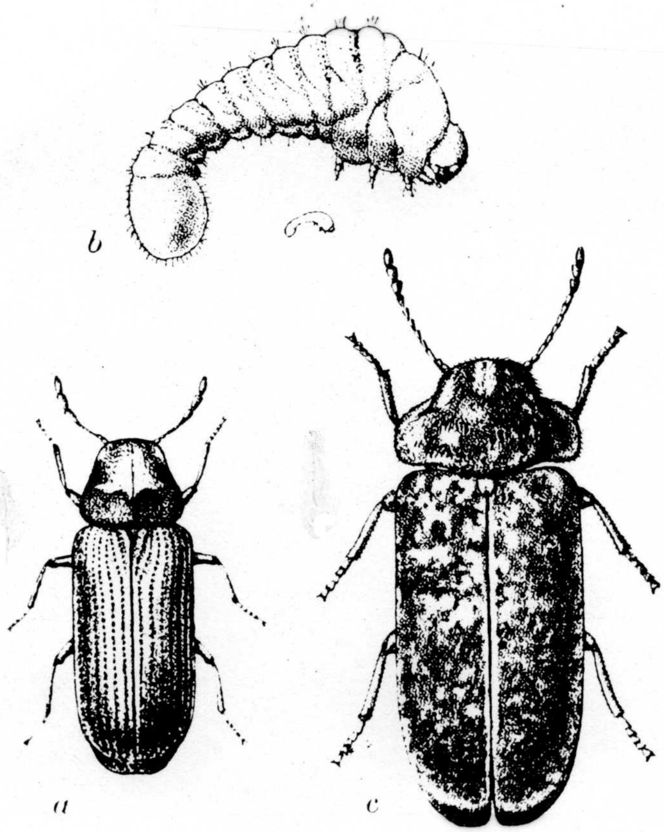
Apart from the exit holes caused by adults, it is the larvae that are responsible for the tunneling of wood. This species mainly attacks sapwood in both soft woods and hardwood, but the damage may extend into heartwood. More larvae become established in partly decayed wood than in sound wood. They are more common in old wood than new wood but some antique dealers report that most attacks take place in the first 50 years.

In addition to wood, they attack woodfiber wallboard and they have damaged cardboard and books.

C. Possible Control Measures

Cultural approaches:

1. Remove unneeded infested items, including old furniture and nearby



a - Furniture beetle, *Anobium punctatum* (DeG.). Body 4-6mm long;

b - larvae of furniture beetle;

c - death watch beetle, *Xestobium rufovillosum* (DeG.). Body 7mm long.

dead tree limbs.

2. Do not bring firewood or other infested wood indoors without prior treatment.

3. Maintain low humidities (below 60% R.H.) to discourage egg hatch.

4. Reduce the moisture content of wood.

5. Maintain low ambient temperatures to prevent insect development.

6. Freeze infested items to kill insects.

7. Heat infested items to kill insects (greater risk of wood damage than freezing).

8. Irradiate infested items to kill insects.

Mechanical approaches:

1. Seal vulnerable items in beetle resistant containers.

Trapping approaches:

No information.

Chemical approaches:

1. Surface sprays of residual insecticide to infested or vulnerable wood (especially unfinished wood), e.g. lindane, bendiocarb, chlorpyrifos, pentachlorophenol.

2. Injections of residual insecticides into infested wood via exit holes or newly drilled holes, e.g. aerosols with crack and crevice injection tubes.

3. Lindane smoke generators in infested areas (especially unfinished attics).

4. Wood fillers to seal exit holes, wood pores and crevices (e.g. wax).

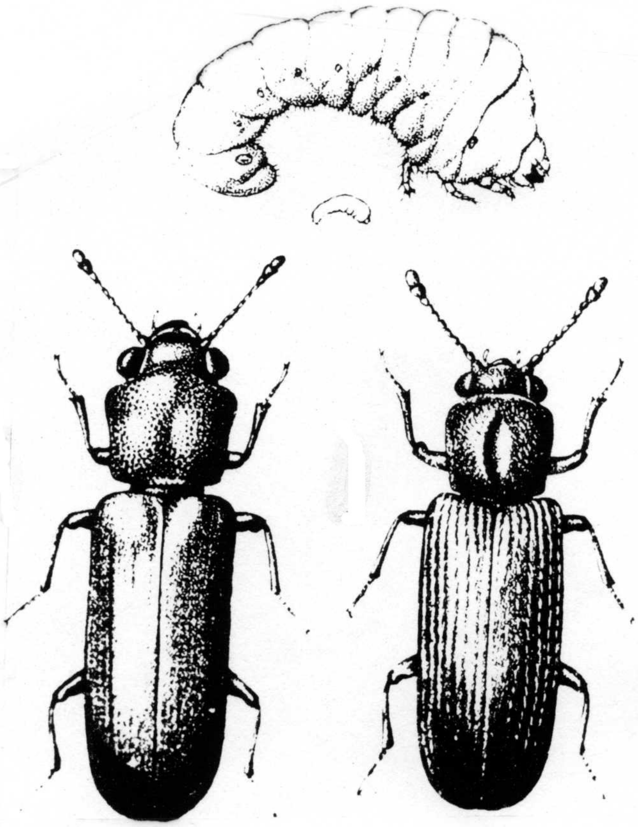
5. Paint, varnish, etc. to coat unfinished wood.

6. Fumigation with standard fumigants (e.g. ethylene oxide, methyl bromide or sulfuryl fluoride) or atmospheric gases.

7. Dipping infested wood in pentachlorophenol or lindane solutions.

D. Promising Areas For Research

- Use of repellents (protection afforded by lindane for more than 20 years may be partly attributable to its repellency).



Left   Brown powder post beetle, *Lyctus brunneus* (Steph.). Body 4-5mm long.

Top   - larvae of *L. brunneus*.

Right - European lyctus, *Lyctus linearis* (Goeze). Body 3-7mm long.

PART I: SECTION 10

POWDER POST BEETLES - *Lyctus* spp.

A. Life Cycle and Habits

Under natural conditions these beetles breed in old, dry wood such as dead limbs on trees. They often enter lumber while it is being stored and cured and later emerge from the finished product. They are also brought indoors on firewood. They are believed to attack only hardwoods, such as oak, hickory. Total development may take two to four years but there may be two generations a year in the South.

Females lay a total of about 50 eggs, one or several eggs at a time, deep in the pores of wood or in old exit holes. Egg laying takes place in the spring outdoors but in heated buildings it may be anytime. Eggs hatch in about 10 days. The larvae bore in wood to feed and their burrows follow the grain and usually do not branch. The frass resulting from feeding is a fine, powder-like dust, quite unlike the pelleted frass of the furniture beetle. The larval stage lasts two to nine months or longer, depending on the species, the temperature and the condition of the wood. The full grown larva bores towards the wood surface (within one-eighth inch) and excavates a cylindrical pupal chamber in which it pupates. The pupal stage lasts 12 days to three weeks.

Adults bore their way to the surface and chew their way out through a round exit hole (one to two mm. diameter). As they emerge they push frass out and this is often the first indication of an infestation. The adults feed a little on the surface and mate. They live about 50 days and are most active at night. They are strong fliers and may travel some distance from their original host wood.

B. Feeding Habits and Damage Potential

Almost all damage is caused by the larvae as they feed. Oak, ash, hickory, maple, walnut and bamboo are preferred woods. They have also been known to attack other hardwoods such as magnolia, sweetgum, black gum, birch, persimmon, locust, elm, poplar, sycamore and cherry. Feeding takes place throughout the year in warm areas but under cold conditions the larvae are thought to be torpid.

Indoor items attacked include furniture, tool handles, hardwood floors, wooden display cases, paneling.

C. Possible Control Measures

Same as for the furniture beetle.

D. Promising Areas For Research

- Same as for the furniture beetle. The possibility of trapping flying adults may be worth exploring.

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PART I: SECTION 11

DRUGSTORE BEETLE - *Stegobium paniceum* (L.)

A. Life Cycle and Habits

This is a common pest of homes and storage facilities throughout the world. The adult keeps its legs and antennae close to its body when at rest and this helps it escape detection.

Females lay eggs singly as they crawl on or bore through food materials. A total of 20 to 100 eggs are laid and these hatch in about 10 days. The emerging larvae feed, grow and molt four times over a four to five month period before pupating.

Pupation takes place within the food source and lasts 12 to 18 days. The adults live two to six weeks and, under optimum conditions (83°F), there may be five generations in a year. However, one or two generations is more common at room temperatures.

B. Feeding Habits and Damage Potential

This species has been described as eating "anything except cast iron". It has been known to pierce tin foil and lead sheet. It feeds readily on bread, flour, meal, breakfast foods and spices. It also is recorded as eating leather, wool, hair, manuscripts, books, drugs and a mummy. It can tunnel in wood (e.g. mah-jongg pieces) and it has been known to bore in a straight line through a whole shelf of books.

C. Possible Control Measures

Cultural approaches:

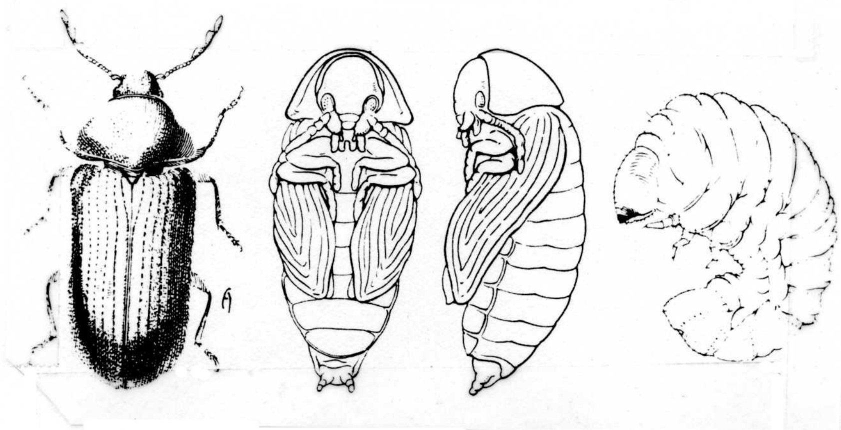
1. Discard infested foods and other replaceable commodities.
2. Freeze infested items.
3. Heat infested items.
4. Irradiate infested items.

Mechanical approaches:

1. Seal vulnerable items in metal or glass containers.

Trapping approaches:

No information.



Adult, pupae and larva of the drugstore beetle, *Stegobium paniceum* (L.) Adult body 2.5mm long.

Chemical approaches:

1. Apply residual insecticide sprays or dusts to create "barriers" on or around vulnerable items (especially bendiocarb products).

2. Fumigate with standard fumigants (e.g. ethylene oxide).

3. Aerosols of pyrethrins (e.g. automatic time-release metered units).

D. Possible Areas For Research

- Investigate trapping parameters.

- Investigate pheromone possibilities for monitoring or control.

- Test new pyrethroids (e.g. permethrin) as mist applications.

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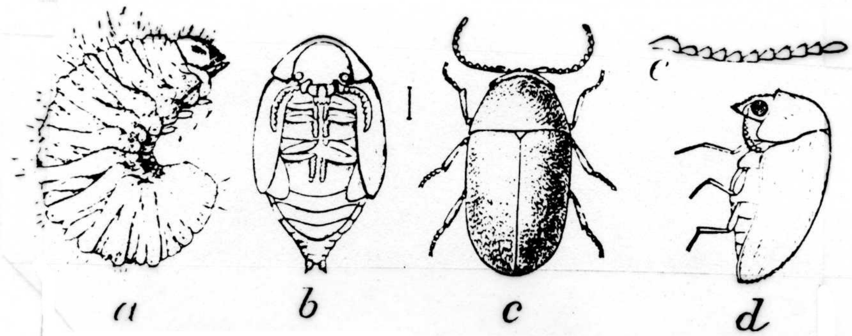

Cigarette beetle, *Lasioderma serricorne* (F.)

a - larva; b - pupa; c and d - adult (2-3mm long);

e - antenna.

PART I: SECTION 12

CIGARETTE BEETLE - *Lasioderma serricorne* (F.)

A. Life Cycle and Habits

While commonly infesting tobacco warehouses, these beetles occur in many storage facilities and periodically in summer they fly in large numbers, usually in the late afternoon and on cloudy days to adjacent homes and other buildings. There may be three generations a year in warm locations but only one in cooler areas.

Females lay about 30 eggs over a period of about three weeks on tobacco or other stored food sources. The eggs hatch in six to 10 days. The larvae avoid the light and feed and complete their development in five to 10 weeks. At about 60°F the larvae become dormant and it is this stage which overwinters. The pupal stage lasts one to three weeks and is spent in a pupal "cell" in the food. The adults are strong fliers and are active in subdued light above 65°F. In summer they live one to six weeks.

B. Feeding Habits and Damage Potential

In addition to eating tobacco this beetle is a serious pest of books, eating the binding and the pages. It is the chief pest in herbaria, chewing holes in specimens. Other items they eat include spices, rice, raisins, dried fish, silk and pyrethrum powder strong enough to kill cockroaches. They severely injure furniture upholstered with flax tow or straw. Most damage is caused by the larvae.

C. Possible Control Measures

Cultural approaches:

1. Discard infested foods and other replaceable commodities.
2. Vacuum up exposed adults from window ledges, etc.
3. Store vulnerable items at low temperatures (55°F or below).
4. Freeze infested items to kill all stages.
5. Heat infested items to kill all stages.

Mechanical approaches:

1. Use screens to exclude adults from entering from outside.

2. Seal vulnerable items in metal or glass containers.

Trapping approaches:

1. Electric light traps activated during peaks of activity.

2. Sticky traps in vicinity of vulnerable items.

Chemical approaches:

1. Use of methoprene insect growth regulator.

2. Apply residual insecticide sprays or dusts to create "barriers" on or around vulnerable items (esp. bendiocarb products).

3. Fumigate with standard fumigants or atmospheric gases.

4. Aerosols of DDVP (e.g. 2 g/1,000 cu ft., twice a week). This beetle is somewhat resistant to pyrethrins.

D. Possible Areas For Research

- Investigate use of pheromone traps for monitoring or control.

- Test new pyrethroids (e.g. permethrin) as mist applications.

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PART II

PEST MANAGEMENT APPROACHES

INTRODUCTION

In Part I, for each key pest, a summary of the control options was given. These options were organized into four broad categories: cultural approaches, mechanical approaches, trapping and chemical approaches. In Part II these options are categorized more narrowly into 12 sections. These sections are as follows:

1. Use of insect resistant containers.
2. Use of heat.
3. Use of non-heat forms of radiation.
4. Use of low temperature.
5. Use of parasites, diseases and predators.
6. Miscellaneous non-chemical methods.
7. Use of conventional insecticides and fumigants.
8. Use of atmospheric gases.
9. Use of non-conventional or low toxicity pesticides.
10. Use of conventional chemicals in non-conventional ways.
11. Use of pheromones.
12. Use of combinations of methods in IPM programs.

For each of these 12 sections an overview is given of the known efficacy and safety of the methods within each section. It is important to remember that all of these methods, both chemical and non-chemical methods, were developed for purposes other than protection of museum collections. Some of them were developed to protect people from annoying or health-threatening pests, and some were developed to protect buildings and their contents from destructive pests. The methods most relevant to protection of museum collections are those designed to protect wood, food and fiber products in residential and commercial buildings. Indeed, few pest control options would be available to museums unless other industries had researched and developed control methods. Unfortunately, methods developed for other industries cannot automatically be transferred to the museum field. This is because the items which are the object of control measures in museums are often more delicate, more rare and more valuable than items elsewhere. Moreover, there is commonly an objective to preserve museum items for much longer periods than items found in homes and industry, and hence more thought must be given to the long-term adverse effects of particular control measures.

A review of pest biology and control literature further emphasizes how little work has been oriented to the needs of museums. However, there are no unique museum pests, and the people who implement, or benefit from, pest control measures in other fields are just as concerned about personal safety aspects as museum workers. Hence, museums can greatly benefit from pest control work in other fields and the challenge is to select and adapt methods to fit the particular needs of museums. In doing this we have to accept that there are no zero risk options for protecting collections. Simply examining or moving collections involves risk. But we must also recognize that to do nothing to protect a collection is to condemn it to destruction by pests.

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PART II: SECTION 1

USE OF INSECT RESISTANT CONTAINERS

Various forms of packaging have been developed by the food industry to help extend the shelf-life of food products. Many of these packages are based on paper or cardboard, sometimes waxed or otherwise coated to keep out moisture. Such packaging is not insect-proof, certainly not against beetles such as the cigarette beetle, but it does provide protection against less aggressive pests such as moths. A disadvantage of paper or cardboard packaging is that it may become a food source for insects which eat cellulose or glue, and it must be disposed of immediately it has served its purpose.

Packages based on plastic sheeting can be even more insect resistant than paper/cardboard, provided they are thick enough and are well sealed. Polyethylene and polypropylene have shown particular promise in resisting insects. Plastic bags are useful for providing temporary protection to vulnerable museum items during transit or as holding containers during and after irradiation. However, care must be taken to prevent condensation which might damage the contents. Moreover, some plastics disintegrate quickly, making gases which harm fabrics and other cultural items.

Metal foil wrappings prevent entry of most insect pests, but they can be pierced by hide and drugstore beetles.

Good insect protection is provided by sealable plastic containers of the Tupperware® type and even better protection by sheet metal boxes or drums and by glass containers. The perfect protection of mounted birds within glass domes is testimony to the value of glass as an insect barrier. Entomological collections can be safely housed in close fitting glass or plastic cases but security is breached whenever they are opened for study and particularly when they are left open an unnecessarily long time.

The integrity of storage and display cases can be checked by enclosing sticky traps inside with the collection. At least some invading insects are likely to be caught on the trap. Periodic inspection of the traps is easier than inspection of the collection, and much better than the common practice of waiting for an item to visually deteriorate before taking action.

It hardly needs stating that insect-resistant or insect-proof packaging, storage and display containers only serve a preventive role. If infested items are placed in them they are likely to remain infested, but at least this infestation is less likely to spread to other areas.

BIBLIOGRAPHY

SECTION 1 - Insect-resistant Containers

BAILEY, S. W. 1965. Air-tight storage of grain; its effect on insect pests. IV. *Rhyzopertha dominica* (F.) and some coleoptera that infest stored grain. J. Stored Prod. Res. 1(1): 25-33.

BATTH, S. S. 1970. Insect penetration of aluminum-foil packages. J. Econ. Entomol. 63(2): 653-55.

Larvae of *Trogoderma inclusum* and cadelle can perforate the 4-mil aluminum foil presently used for packaging dehydrated soup mixes, whereas sawtoothed beetle can not.

BRY, R. E., et al. 1972. Protecting stored woolens against fabric-insect damage. A long-term nonchemical method. J. Econ. Entomol. 65(6): 1735-36.

Heat-sealed, kraft-polyethylene case liners gave long-term complete protection of enclosed clean woolens from a variety of fabric pests and mildew.

CLINE, L. D. 1978. Clinging and climbing ability of larvae of eleven species of stored-product insects on nine flexible packaging materials and glass. J. Econ. Entomol. 71(4): 689-91.

Larvae of *Ephestia cautella*, *Corcyra cephalonica*, *Plodia interpunctella*, *Anthrenus flavipes*, *Dermestes maculatus*, *Tribolium castaneum*, *Oryzaephilus mercator*, *Cathartus quadricollis*, *Trogoderma variabile*, *Attagenus megatoma* and *Lasioderma serricorne* were tested for their ability to climb paper, glass, aluminum foil, cellophane, polyethylene, fluorinated ethylenepropylene ethylenetetrafluoroethylene, polyester, polyvinylchloride and polypropylene at various angles up to 90@. Results are given in tables and discussed.

CLINE, L. D. 1978. Penetration of seven common flexible packaging materials by larvae and adults of eleven species of stored-product insects. J. Econ. Entomol. 71(5): 726-29.

The ability of larvae to penetrate packaging materials was determined for large and small larvae of *Oryzaephilus mercator*, *Cathartus quadricollis*, *Cryptolestes pusillus*, *Tribolium castaneum*, *Tenebroides mauritanicus*, *Trogoderma variabile*, *Dermestes maculatus*, *Lasioderma serricorne*, *Ephestia cautella*, *Corcyra cephalonica* and *Plodia interpunctella*. Materials tested were cellophane, polyethylene, paper, polyvinylchloride, aluminum foil, polyester and polypropylene. Foil, polyester and polypropylene were generally the most resistant to penetration.

CLINE, L. D. and H. A. HIGHLAND. 1978. Survival of four species of stored-product insects in airtight laminated food pouches. J. Econ. Entomol. 71(1): 66-68.

Eggs, larvae or adults of *Lasioderma serricorne*, *Plodia interpunctella*, *Tribolium castaneum* or *Trogoderma variabile* were introduced with food in

airtight paper-foil-polyethylene or polyester-foil-ionomer pouches. Only a few L. serricorne introduced as larvae survived past 12 wk but they were so adversely affected that they failed to develop further when removed from the pouches.

HIGHLAND, H. A. 1980. Resistant barriers for stored-products insects. In: CRC Handbook of Transportation and Marketing in Agriculture. Volume I. Food Commodities. CRC Press: 41-46.

The author reviews the resistance of various packaging materials to penetration by stored-product pests.

HIGHLAND, H. A., L. D. CLINE and R. A. SIMONAITIS. 1977. Insect-resistant food pouches made from laminates treated with synergized pyrethrins. J. Econ. Entomol. 70(4): 483-85.

Heat-sealed pouches of glassine paper that was laminated with adhesive plus synergized pyrethrins to aluminum foil and either polyethylene or an ionomer provided good protection during 12 months exposure time to penetrating insects.

HIGHLAND, H. A., et al. 1969. 1969 status report of stored-product insects research of military importance: 1. Packaging materials and constructions. 2. Simulated or practical storage studies. (Two articles). USDA Stored-Prod. Insects Res. Dev. Lab., Savannah, Ga., AFPCB Savannah, Mar. 10-14: 16; 17.

1. Ethylene vinyl actate resin reduced migration of piperonyl butoxide into flour. 2. Shipping test with treated bags of cornmeal gave excellent results.

HIGHLAND, H. A., M. SECREAST and D. A. YEADON. 1975. Insect-resistant textile bags: new construction and treatment techniques. USDA ARS Tech. Bull. No. 1511: 12pp.

LAUDANI, H., et al. 1958. Improved packaging methods can cut insect infestation. Mod. Sanitat. Build. Maintenance 10(3): 17-21, 52.

Textile bag and paper bag packaging for resistance to penetration by insects.

RAO, K. M., S. A. JACOB and M. S. MOHAN. 1972/73. Resistance of flexible packaging materials to some important pests of stored products. Indian J. Entomol., New Delhi 34(2): 94-101.

Resistance of 23 types of flexible packaging materials to six species of insects were determined.

WILKIN, D. R., et al. 1970. Polythene sacks for the control of insects in bagged grain. J. Stored Prod. Res. 6(1): 97-101.

When confined in polythene outer sacks of 0.127 mm wall thickness, mixed populations of Oryzaephilus surinamensis and Sitophilus granarius were killed in 3 days.

YERINGTON, A. P. 1979. Methods to increase the insect resistance of food shipping cases. USDA Sci. Educ. Admin., Adv. Agric. Technol., Oakland Ser. No.: 5p.

Four methods of packaging food shipping cases of dried fruit were evaluated to determine which modification would reduce stored-product pest infestations. The most effective method included the overwrapping of individual cartons with a 1.7 mil polyethylene liner.

PART II: SECTION 2

USE OF HEAT

Heat is one of the most certain means of killing insects, and is much more reliable than using low temperatures. However, heat accelerates all processes, including oxidation, which is a component of most aging processes. As a result, it can be said that heat accelerates aging.

Heat is the oldest, most common and often the most satisfactory method used in the food industry to kill bacteria and insects. It can be derived from steam, hot air, combustible gases or various forms of radiant energy, including infrared and microwaves.

Heat can be used on a small scale or a large scale. Some museums use small incubators for routine heat sterilization of trays of insects. In the food industry, whole buildings are sometimes heated to eradicate insects. One case is known of a library being heated to eliminate cigarette beetles. The notes accompanying the references in the bibliography describe the susceptibility of particular pests to heat. Some, such as the webbing clothes moth, are very vulnerable and all stages are killed after only 4 hours at 105°F. Others, particularly some of the beetles, require higher temperatures or longer exposure, or both. Nonetheless, heat should always be considered as a possible alternative to fumigation, not least because it leaves no residue, requires no aeration afterwards, can be conducted by uncertified workers without risk to themselves and can be 100% effective on all insect stages.

However, before using heat on infested items, it is essential that experts agree that any resulting ill effects on the items are likely to be within acceptable limits. Items such as mounted insect collections appear to tolerate heat very well, but the trays in which the insects are housed may buckle or warp if they are multi-media or wooden construction. Such warping would in turn render the collection more vulnerable to future invasion by insect pests.

Regarding heat treatment of wood for control of powder post or furniture beetles, it is important to adjust the relative humidity as the temperature changes in order to maintain the Equilibrium Moisture Content. In other words, the R.H. must rise as the temperature rises, and fall when the temperature returns to normal.

Wood boring larvae are generally killed by a temperature of 125°F for three hours, but this temperature may be harmful to wooden objects having adhesive layers or differential wood orientation. To minimize risk, an evaluation of the adhesive flow temperature should be made, as well as an evaluation of grain orientation across supports, braces and joints to ensure that acceptable tolerances exist. In addition, as mentioned above, the R.H. must be regulated. For large objects exhibiting a localized infestation, spot heat treatment with a lamp can be effective without heating the whole object.

For most insect pests a temperature of 130°F for a few hours is effective, and this can be achieved easily and economically with available equipment.

BIBLIOGRAPHY

SECTION 2 - Use of Heat

ARBOGAST, R. T. 1981. Mortality and reproduction of *Ephestia cautella* and *Plodia interpunctella* exposed as pupae to high temperatures. Environ. Entomol. 10(5): 708-11.

The effects of brief exposure of almond moth and Indianmeal moth pupae to high temperatures were reported. The almond moth was significantly more tolerant of high temperature than the Indianmeal moth. The effects on adult eclosion, mating, fecundity, and fertility of survivors were also discussed.

BECKER, G., et al. 1961. Heat susceptibility of wood-destroying beetle larvae. Anz. Schadlingsk. 34(10): 145-49.

At 55°C it required 75 minutes to kill all larvae of *Hylotrupes bajulus* and 30 minutes to kill larvae of *Anobium punctatum* and *Lyctus brunneus* when these beetles were placed in pine sapwood.

BELL, C. H. 1983. Effect of high temperatures on larvae of *Ephestia elutella* (Lepidoptera: Pyralidae) in diapause. J. Stored Prod. Res. 19(4): 153-57.

The effect of constant and intermittent exposures to temperatures between 40-45°C on the mortality and pupation rate of diapausing *Ephestia elutella* larvae was studied. Exposures at the higher temperatures significantly hastened the termination of diapause, this could be correlated with the level of mortality achieved. However, repeated short-term exposure to high temperature not only lowered mortality, but increased the rate and synchronisation of pupation. Thus any treatment using heat for control of this insect, must last for a sufficient duration greater than 8 hours to produce the desired results.

COOMBS, C. W. 1978. The effect of temperature and relative humidity upon the development and fecundity of *Dermestes lardarius* L. (Coleoptera, Dermestidae). J. Stored Prod. Res. 14(2/3): 111-19.

Colonization and development at various combinations of temperature and humidity are recorded. The range of limits for temperature appeared to be about 15°C and 32.5°C. Optimum rearing conditions are discussed.

CRESSMAN, A. W. 1935. Control of an infestation of the cigarette beetle in a library by the use of heat. J. Econ. Entomol. 26: 294-5.

Describes use of bas burners in a New Orleans library to maintain a temperature of 140-145°F for six hours. Electric fans were used to maintain an even temperature distribution. The books were loosened to facilitate air circulation. All stages of the beetles were eliminated with no damage to the books which were bound in sheepskin and buckram.

GODKIN, W. J. and W. H. CATHCART. 1949. Effectiveness of heat in controlling insects infesting the surface of bakery products. Food Technol. 3: 254-257.

Using an infrared exposure temperature of 500°F it is possible to heat the surface of a finished package product like fruit cake to 140-150°F within 20 seconds. This is sufficient to kill insects without altering the food or damaging the cellophane packaging.

HAMID, M. A. K., et al. 1968. Control of grain insects by microwave power. J. Microwave Power 3(3): 125-37.

Survey and control techniques.

HAMID, M. A. K., et al. 1969. A new method for the control of moisture and insect infestations of grain by microwave power. J. Microwave Power 4(1): 11-18.

Method based detection of dielectric properties of these insects.

JACOB, T. A. and D. A. FLEMING. 1980. Some observations on the effects of temperature and relative humidity upon pupation, fecundity and the longevity of Dermestes lardarius L. (Coleoptera: Dermestidae). J. Stored Prod. Res. 16(2): 79-80.

At 30°C adults lived only up to 36 days and none of the females laid eggs, whereas adults obtained at 15°C were morphologically normal and lived up to 211 days. Most females failed to lay eggs.

JACOB, T. A. and D. A. FLEMING. 1984. Some further observations on the effect of temperature on the fecundity and longevity of Dermestes lardarius L. (Coleoptera: Dermestidae). J. Stored Prod. Res. 20(1): 7-9.

The median life-span of adult Dermestes lardarius was longest at 17.5 and 20°C, and shortest at 30°C. The effect of temperature on oviposition was studied, with the longest recorded at 20°C and shortest at 27.5°C. Temperature also had a direct influence on number of eggs laid.

KAWAHARA, S. 1959. The influences of temperature upon the growth and reproduction of the case-bearing clothes moth, Tinea pellionella (L.). Botyu-Kagaku 24(4): 191-99.

Optimum temperature 27-30°C.

KENAGA, E. E. and F. W. FLETCHER. 1942. Effects of high temperature on several household and storage grain pests. J. Econ. Entomol. 35(6): 944.

A temperature change from 80°F to 105°F killed 100% of Tineola bisselliella eggs and adults and 90% of larvae. Approx. 50% of the larvae and adults of Attagenus megatoma and Dermestes sp. were killed.

KIRKPATRICK, R. L. 1974. The use of infrared and microwave radiation for control of stored-product insects. Proc. 1st Int. Work. Conf. Stored-Prod. Entomol., Savannah 7-11 Oct: 431-38.

The eggs and young larvae of lesser grain borers, Rhyzopertha dominica, and angoumois grain moths, Sitotroga cerealella, infesting wheat were more resistant to infrared radiation than were the eggs and young larvae of rice weevils, Sitophilus oryzae. Microwave tests showed that the mature larvae and pupae of angoumois grain moths, rice weevils, or lesser grain borers were more resistant to microwave energy than either the young larvae or eggs.

KIRKPATRICK, R. L. 1975. Infrared radiation for control of lesser grain borers and rice weevils in bulk wheat (Coleoptera: Bostrichidae and Curculionidae). J. Kans. Entomol. Soc. 48(1): 100-04.

Beetles were exposed to infrared radiation that raised the temperature to 48.6°C. After 24 hours, 93 and 99% of the lesser grain borers and rice weevils had been killed.

KIRKPATRICK, R. L. and A. CAGLE. 1978. Controlling insects in bulk wheat with infrared radiation. J. Kans. Entomol. Soc. 51(3): 386-93.

Natural infestations of rice weevils, lesser grain borers, flat grain beetles, and red flour beetles were controlled in bulk wheat by heating to 55°C by infrared radiation.

KIRKPATRICK, R. L., et al. 1972. Infrared radiation to control adult stored-product Coleoptera. J. Ga. Entomol. Soc. 7(1): 73-75.

Mortality among 12 species of stored-product beetles in soft winter wheat was 99.6% or more for each species tested when infested grain was exposed to infrared radiation at a temperature of 65°C.

KIRKPATRICK, R. L., et al. 1972. A comparison of microwave and infrared radiation to control rice weevils (Coleoptera: Curculionidae) in wheat. J. Kans. Entomol. Soc. 45(4): 434-38.

Microwave or infrared radiation was used to produce a temperature of 54 ± 1°C in paired samples of rice weevil infested soft winter wheat. Infrared gave greater insect control than did microwave by the following average differences in percentage: 13 for immature stages, 76 for adults, and 56 for F1 progeny of treated adults.

KIRKPATRICK, R. L., et al. 1973. Elevated temperatures to control insect infestations in wheat. J. Ga. Entomol. Soc. 8(4): 264-68.

Ninety-nine percent or more control was obtained at 39 ± 1°C with a relative humidity of 60% for the rice weevil and at 43.3 ± 1°C with a relative humidity of 50% for the lesser grain borer.

MAUDLIN, J. K. 1983. The forest service research program on protection of wood in use. Pest Management 2(1): 14, 16, 19.

Review of research by USDA Forestry Sciences Laboratory at Gulfport, Mississippi. Mentions that Dursban is now federally registered for control of Anobiidae, Cerambycidae and Lyctidae beetles in wood. States intention to test control of active beetle infestations in small items using freezing, or heating them with infrared or microwave radiation.

OKUMURA, G. 1982. Stored Product Pests (in the Handbook of Pest Control, 6th Edition). Franzak & Foster, Cleveland. Chapt. 16: 507-591.

Heating infested material at 60° to 80°C for several hours kills all stages of the drugstore beetle.

PCO NEWS. 1966. Do moths use radar? PCO News 26(3): 62-63.

Infrared light as an attractant. UHF for control of grain pests. Bacillus popilliae to control Japanese beetle.

PENCE, R. J. 1956. UCLA's infrared radiation unit to control lyctus powder-post beetle infestations in hardwood floors can be built by PCOs. Pest Control 24(7): 30, 32, 34, 36.

SNYDER, T. E. and R. A. ST. GEORGE. 1924. Determination of temperatures fatal to the powder-post beetle, Lyctus planicollis LeConte, by steaming infested ash and oak lumber in a kiln. J. Agr. Res. 28: 1033-8.

Insects are killed in wood up to one inch thick after 1½ hours at 130°F in a live steam kiln. This procedure will damage fine finishes. Longer exposure is required for thicker wood.

SWEETMAN, H. L. 1938. Physical ecology of the firebrat Thermobia domestica Packard (Lepismatidae) in Canada. Canad. Entomol. 62: 1-2.

Temperatures below 32°F and above 112°F readily kill nymphs of firebrats.

SWEETMAN, H. L. 1939. Responses of the silverfish, Lepisma saccharina L. to its physical environment. J. Econ. Entomol. 32: 698-700.

Optimum conditions for silverfish are 72° to 80°F and 75% to 97% relative humidity. Nymphs are killed above 98°F.

SWEETMAN, H. L. 1941. The pest thysanuraus of New England. Pests 9(6): 8-9.

Optimum conditions for development of the firebrat are 90° to 106°F.

TILTON, E. W. and H. H. VARDELL. 1982. Combination of microwaves and partial vacuum for control of four stored-product insects in stored grain. J. Ga. Entomol. Soc. 17(1): 106-12.

Stored-product insect infestations in stored grains can be reduced or controlled by a combination of microwave heating and partial vacuum. Sitotroga cerealella was controlled in rye and corn and 96.8% in wheat. Rhyzopertha dominica was controlled in corn and 99.4% in rye and 95.6% in wheat. Sitophilus oryzae was controlled by 99.2% in wheat and completely in rye and S. zaemais was controlled in corn.

VAN DEN BRUEL, W. E., et al. 1960. Study of factors determining the possibilities of using dielectric heat at high frequency for the destruction of insects and mites deeply concealed in packed foods. Parasitica, Gembloux, Belgium. 16(2): 29-61.

An extensive report is given of methods, equipment, insects and stored-products used in research of dielectric heat at high frequency (40-80 Mhz) for control of such pests. Temperature is a very important factor with this form of control. Recommendations are given for use such as rigid-material packing containers must be used and degree of compaction must be known. Insects used: Tribolium confusum, Laemophloeus sp., Ephestia kuhniella, Gnathocerus cornutus, T. castaneum and Sitophilus oryzae.

VARDELL, H. H. and E. W. TILTON. 1981. Control of the lesser grain borer, *Rhyzopertha dominica* (F.), and the rice weevil, *Sitophilus oryzae* (L.) in rough rice with a heated fluidized bed. J. Ga. Entomol. Soc. 16(4): 521-24.

Grain temperatures of 62° and 58°C completely controlled all life stages of the lesser grain borer and the rice weevil in rough rice treated in a heated fluidized bed. It was not necessary to maintain these grain temperatures once treatment temperatures were reached.

WATTERS, F. L. 1962. Control of insects in foodstuffs by high-frequency electric fields. In: Unconventional approaches to insect control, Annual Meeting, 1961, Hamilton, Ontario. Proc. Entomol. Soc. Ontario 92(1961): 26-32.

Use of electric fields appears to be limited. The lethal effect is considered by most workers to be due entirely to the induction of high temperatures within the insects.

RAWLE, S. G. 1951. The effects of high temperatures on the common clothes moth, *Tineola bisselliella* (Hum.). Bul. Entomol. Res. 42(1): 29-40.

At 70% R.H. all stages of the moth died when exposed to 105.8°F for four hours. All stages can survive at 91.4°F. Low heat tolerance may explain why this moth is not reported in tropical climates.

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PART II: SECTION 3

USE OF NON-HEAT FORMS OF RADIATION

There is a broad spectrum of radiation, much of which we are exposed to daily, if only in small amounts. These radiations are defined by their wavelengths, which range from millionths of a millimeter up to thousands of meters. At the short wave end there are cosmic rays which emanate from outer space. At a slightly longer wavelength is gamma radiation which arises from commonly occurring radioactive substances. Next on the scale come X-rays, then ultraviolet radiation. Then comes the visible light range, from deep violet at the shorter wavelength to deep red at longer wavelengths. Beyond the visible light comes the infrared band of radiation, the heat rays. Then at still longer wavelengths is the form of radiation known as radio waves. Finally, there is radiation with a wavelength so long that it is best transmitted through conductors, such as copper wire; this is known as electricity.

With the exception of cosmic rays, all these forms of radiation have been used, or researched, for pest control purposes. The use of heat has already been mentioned. Visible light is used as a lure in light traps (see later). Electricity has been used in electrified strips around the edges of containers used for breeding insects such as German cockroaches. These electrified strips prevent the insects escaping because whenever an insect contacts the strip it is stunned and falls down. Presumably such strips could be incorporated in display or storage areas to prevent entry of crawling pests. Of course, flying pests can bypass such strips.

Another use of electricity is in the so-called "electron gun", which is reported to be capable of killing drywood termites and powder post beetles in buildings and furnishings. This device generates a high voltage (90,000 volts), at high frequency (15 kilohertz) but low current (50 watts), which is used to electrocute insects. The prototype device was built in 1978 and it became commercially available in 1980. Commercial users report generally comparable results to fumigation and better results than when drilling and injecting insecticides. However, some preliminary tests in Texas organized by the Structural Pest Control Board showed that electron guns failed to control drywood termites in three out of five homes. In addition, some scorching of wood may result from the electric treatment.

Undoubtedly the greatest use of non-heat forms of radiation is gamma radiation for sterilizing food and medical items. Gamma radiation is characterized by its deep penetration and low dose efficacy. Cobalt-60 is the source of gamma radiation in current facilities. At present there are about 20 large scale gamma radiation facilities in the United States and several are under construction. Use of gamma radiation is much more widespread in Europe, but the increasing concern about alternatives such as ethylene oxide (EO) is now making every large U.S. medical equipment manufacturer evaluate conversion from EO to radiation. Moreover, with the increased costs necessary to meet the tighter regulations imposed on use of EO it may be cheaper to use gamma radiation than EO.

The key advantages of gamma radiation are better kill of pests and greater safety to those who subsequently handle the items. Gamma rays uniformly penetrate objects, and in the case of museum items the irradiation could take place within sealed containers used for shipping or storage. This avoids the handling needed to ensure penetration of fumigants such as EO.

Regarding safety, gamma radiation leaves no residues and, since gamma rays have no mass, does not leave materials radioactive. Since gamma radiation takes place with no appreciable change in temperature or pressure, fewer stresses are placed on materials than in vacuum fumigation with relatively reactive fumigants such as EO. However, some plastics are adversely affected by gamma radiation, especially polyacetals, some grades of polypropylene and fluorocarbons. Moreover, some plastics (e.g. PVC and acrylics) and glass can exhibit a color change. In addition, gamma radiation is known to cause both micro- and macrostructural changes to cotton, including cracking of the fiber surface and loss of tensile strength. For these reasons tests would need to be conducted to determine what types of museum material are suitable for gamma radiation.

The food and health care industries have been leaders in developing new pest control technologies which take into account both product and user safety. The current trend in these industries to adopt gamma radiation is a clear indication that other sectors, such as the museum sector, should look to this technology as an alternative to fumigation. Initially, selected items could be shipped to commercial gamma radiation facilities for contract irradiation. Ultimately, consideration could be given to building an in-house facility to reduce shipping time and risks. Current commercial facilities have an estimated construction price of $3 million. However, the proposed Strategic Defense Initiative is expected to produce one non-military spinoff which may make irradiation facilities more affordable. This spinoff is a powerful miniature particle accelerator, a "mini death ray" device, which is only about 10 feet long.

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BIBLIOGRAPHY

SECTION 3 - Use of Non-heat Forms of Radiation

ABDU, R. M. and N. F. SHAUMAR. 1974. Gamma-irradiation of immature stages of the beetle Dermestes frischii (Kug.). Z. Angew. Entomol., Hamburg 75(1): 103-06.

Newly hatched and last instar larvae of D. frischii were exposed to different levels of gamma radiation. Larval and pupal periods were increased with increased doses and longevity of emerging adults was decreased.

AHMED, C. R. 1975. Effect of gamma radiation on eggs of Trogoderma granarium Everts. J. Stored Prod. Res. 11(3/4): 245-47.

ANONYMOUS. 1964. Non-chemical insect control. HEW News Summary 14(140): 3.

Continuous low hum from radio loudspeakers caused mortality of Indian meal moths.

ANONYMOUS. 1984. RSI Gammagram # 101 - What is radiation sterilization? Radiation Sterilizers, Inc., Schaumburg, Ill. 2pp.

Description of the process flow for receiving, treating and despatching materials in a commercial gamma radiation facility.

ANONYMOUS. 1984. RSI Gammagram # 200 - Why gamma sterilize? Radiation Sterilizers, Inc., Schaumburg, Ill. 1 page.

Good summary of the effectiveness and other benefits of gamma irradiation compared with use of ethylene oxide for destroying microorganisms.

ASHRAFI, S. H., et al. 1972. Inheritance of radiation-induced partial sterility in the Indian meal moth. J. Econ. Entomol. 65(5): 1265-68.

Radiation of 5th-stage larvae of 3.5 krad caused a 72% reduction in numbers of offspring in the F1 generation. When F1 males were mated with normal females, there was a 89% reduction in the F2 generation. Effective sterilizing dosages for adults (30-45 krad) reduced mating competitiveness.

BANHAM, E. J. 1962. The susceptibility of the confused flour beetle (Tribolium confusum Duv.) to gamma radiation. Porton Abst. 126.181, Chem. Dev. Lab. 27320 (Eng.): -.

A dose of 16,000 rads effective for complete sterilization of confused flour beetles, grain and rice weevils.

BOLLAERTS, D., et al. 1961. New investigations relating to the use of the properties of microwaves for the destruction of insects hidden in wood. Mededelingen, Agric. Univ. and State Exp. Station, Ghent, Belgium 36(3): 1435-50.

Damage by *Lyctus brunneus* to woodwork interrupted after treatment. No further damage after six months.

BROWER, J. H. 1973. Sensitivity of *Tenebrio molitor* and *T. obscurus* to gamma irradiation. J. Econ. Entomol. 66(5): 1175-79.

Effects of gamma irradiation doses between 5 and 100 krad on all stages of *Tenebrio molitor* and *T. obscurus* appeared to be similar although *T. molitor* was more radiosensitive. Control of these 2 species appears feasible with the levels of irradiation currently approved for treatment of stored-grain insects in wheat and wheat flour.

BROWER, J. H. 1974. Radiosensitivity of the squarenecked grain beetle, *Cathartus quadricollis* (Guerin-Meneville) (Coleoptera: Cucujidae). J. Kans. Entomol. Soc. 47(2): 254-59.

Five krad of gamma irradiation to eggs and larvae prevented the development of adults but adults emerged from pupa treated with up to 50 krad.

BROWER, J. H. 1974. Potential for genetic control of stored-product insect populations. Proc. 1st Int. Work. Conf. Stored-Prod. Entomol., Savannah 7-11 Oct: 167-80.

Genetic manipulation of natural insect populations is being used to control at least three species and research with others is promising. Little effort has been directed against stored-products pests. These insects offer unique advantages for the successful application of new control techniques and could serve as models for genetic control of other species. Advantages and disadvantages of the techniques are described. Species considered are *Cochliomyia hominivorax*, *Pectinophora gossypiella*, *Anastrepha ludens*, *Tribolium confusum*, *Anagasta kuehniella*, *Cadra cautella*, *Anthonomus grandis*, *Musca domestica*, *T. castaneum*, *Diatraea saccharalis*, *Dermestes maculatus*, *Drosophila melanogaster*, *Trogoderma* spp., *Plodia interpunctella*, *Xylocoris flavipes*, *Sitophilus*, etc.

BROWER, J. H., et al. 1972. Gamma-radiation effects on *Trogoderma inclusum* and *T. variabile*. J. Econ. Entomol. 65(1): 250-54.

Effects of gamma radiation exposures of 5-100 krad on all developmental stages of *Trogoderma inclusum* LeConte and *T. variabile* Ballion were studied. No reproduction occurred at 30 krad or above, a dosage well within the legally approved level.

BROWER, J. H., et al. 1973. Radiation sensitivity of successively irradiated generations of *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae), and *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae). J. Stored Prod. Res. 9(1): 43-49.

Results indicate that substerilizing doses during commercial radiation disinfestation is unlikely to bring about the development of radiation-resistant insect populations.

COHEN, S. H., J. A. SOUSA and F. ROACH. 1973. Effects of UV irradiation on nymphs of five species of cockroaches. J. Econ. Entomol. 66(4): 859-862.

UV can be used to kill roaches.

CONROY, A. E., II. 1980. Investigation of efficacy and enforcement activities relating to electromagnetic pest control devices. EPA Pestic. Toxic. Subst. Enforce. Div., Wash., D.C. 340/02-80-001: 229p.

The results of several exhaustive efficacy tests against major pest species claimed to be controlled by electromagnetic devices are presented in detail as an EPA report. In more than 20 tests against ten species of rodents and insects, there was no demonstrated efficacy in either field, laboratory or simulated field tests. Thus, enforcement actions were advised against all devices which had been tested by EPA regional offices.

EBELING, W. 1985. Electrogun zaps drywood termites. Pest Control Technol. (13)8: 74, 76, 77.

Describes the Electrogun and how to use it, and reports a study of the effectiveness of using the Electrogun to electrocute drywood termites in laboratory tests. Complete kill was obtained. Reference is made to successful commercial use of the Electrogun by contractors against drywood termites and powder post beetles.

Commercial users are reported to find the Electrogun useful for spot treatments of structures and as an alternative to fumigation or drilling and injecting insecticides.

GOLUMBIC, C. and D. F. DAVIS. 1966. Radiation disinfestation of grain and seeds. In: Food Irradiation. Int. At. Energy Agency, Vienna: 473-88.

Research programs in USDA are described. Gaps in the fundamental and practical knowledge of radiation disinfestation are pointed out. Current studies are for the establishment of minimum effective doses for sexual sterilization and mortality, influence of environmental factors on dose requirements, and potential for the development of biological resistance. Work expanded as a new grain products irradiator became operative and applied studies were initiated. The effect of irradiation on the quality of food and feed grains and on cereal products are described.

JEFFERIES, D. J. 1962. The susceptibility of the saw-toothed grain beetle Oryzaephilus surinamensis (L.) to gamma radiation. Porton Abst. 126-182, Chem. Dev. Lab. 27321 (Eng.): -.

KIRKPATRICK, R. L., et al. 1970. Effectiveness of green and ultraviolet light in attracting stored-product insects to traps. Flat grain beetles and lesser grain borer. J. Econ. Entomol. 63(6): 1853-55.

Green and UV + green lights were equally attractive to all stored-products insects tested. The almond moth and the Indian meal moth preferred the green light operating independently. Fewer cigarette beetles were attracted to the green light.

KIRKPATRICK, R. L., et al. 1973. Gamma and microwave radiation to control the rice weevil in wheat. J. Ga. Entomol. Soc. 8(1): 51-55.

Gamma radiation was somewhat more effective than microwave radiation. Mortality in the combined treatments exceeded the calculated expected mortality except for the pre-emerged adult stage.

KIRKPATRICK, R. L., et al. 1973. Gamma, infrared and microwave radiation combinations for control of *Rhyzopertha dominica* in wheat. J. Stored Prod. Res. 9(1): 19-23.

Reductions in emergence averaged 99% for the gamma plus infrared combination and 96% for the gamma plus microwave combination. The combined treatments were much more effective than a single irradiation treatment. Adult fecundity was also greatly reduced in the combined-exposure treatments.

KUMAGAI, M. 1967. Influence of post-treatment humidity on the irradiated rice weevil adult, *Sitophilus zeamais* Motshulsky (Coleoptera: Curculionidae). Appl. Entomol. Zool., Tokyo. 2(1): 51-57.

The data obtained showed the higher the relative humidity, the less the influence of irradiation.

LAUDANI, H., E. W. TILTON and J. H. BROWER. 1965. USDA research program and facilities for the use of gamma-irradiation in the control of stored-product insects. Food Irradiat. Q. Int. Newsl. 6(1/2): A6-A9.

Article describes the USDA's attempt to expand the research to a pilot-plant stage (gamma irradiation) of operation.

MENHINICK, E. F., et al. 1969. Radiation sensitivity of twelve species of arthropods. Ann. Ent. Soc. Amer. 62(4): 711-17.

Of tested species of isopods, beetles, cockroaches, wasps, firebrats, ants and crickets, *Periplaneta americana* most and *Attagenus piceus* least sensitive.

NAIR, K. S. S., et al. 1965. Effects of gamma radiation on the post-embryonic stages of a dermestid beetle, *Anthrenus vorax* Waterhouse. Entomol. Exp. Appl. 8(4): 241-48.

Percentage of successful molts decreased with increasing doses.

NELSON, S. O. 1972. Possibilities for controlling stored-grain insects with RF energy. J. Microwave Power, Canada 7(3): 231-39.

Literature cited concerning insect control with radiofrequency electric fields was reviewed. Consideration of practical aspects indicated that immediate application of radiofrequency methods for insect control is probably not economically feasible, but that radiofrequency methods warranted continued evaluation for future possibilities.

PANAGIOTALIDIS, C. Z. and O. C. LEGA-PANAGIOTALIDIS. 1981. The degradation of cotton by ionizing radiation. Textile Res. J. (May): 311-317.

Describes the effect of gamma radiation on the physical and chemical properties of raw cotton over a range from zero to 120 Mrad. Evaluation techniques included viscometry, infrared spectroscopy, solubility, stress-strain measurements and SEM. The authors conclude that changes in cotton caused by irradiation are both intramolecular and supramolecular (interfibrillar) in nature. There are 21 references to related work.

PENDLEBURY, J. A., et al. 1962. Some effects of gamma radiation on the lesser grain borer, tropical warehouse moth, Indian meal moth and cigarette beetle. Porton Abst. 126.180, Chem. Dev. Lab. 27306 (Eng.): -.

Sixteen thousand rads sterilize lesser grain borer and cigarette beetle but not tropical warehouse or Indian meal moth.

POINTEL, J. G., et al. 1969. Effets des radiations ionisantes sur le developpement de dermestes de Dermestes maculatus Deg. J. Stored. Prod. Res. 5(2): 95-109.

Larvae, nymphs or adults irradiated at dosages ranging from 10 to 30 krad failed to give progeny and their life spans were shortened.

PROCTOR, B. E., et al. 1954. The application of electronic treatments to destruction of insects in packaged military rations and packaging materials. Mass. Inst. Tech. Dep. Food. Technol., Cam., Fin. Rpt. 17 Jun. 52-31 Dec 53, Contr. DA 11-009-QM-19888: 106pp.

The sensitivities of eggs, larvae, pupae, and adults of Tribolium confusum, Oryzaephilus surinamensis, Rhyzopertha dominica, Lasioderma serricorne, and Tenebrio molitor to gamma, cathode, and X-rays are evaluated. Effects of radiation on the physical characteristics of packaging materials and on the flavor of foodstuffs are also investigated.

ROSS, M. H. and D. G. COCHRAN. 1963. Some early effects of ionizing radiation on the German cockroach, Blattella germanica. Ann. Entomol. Soc. Amer. 56: 256-261.

Progressive increase in dormant lethals with an increase in exposure to radiation in the range 100 to 9.600 rads.

RUTHERFORD, H. A. 1963. Radiation effects on organic materials. R. O. Bolt and J. G. Carol, Eds., Academic Press, New York, pp. 431-437.

Makes reference to the degradation of cotton under irradiation. Reports a decrease in crystallinity caused by radiation.

SAEMAN, J. F., M. A. MILLET and E. J. LAWTON. 1952. Effects of high energy cathode rays on cellulose. Ind. Eng. Chem. 44(12): 2848-2852.

Describes effects of high energy radiation on cotton linters, wood and wood pulp.

SAKURADA, I., K. KAJI, T. OKADA and A. TSUCHIYA. 1975. Degradation of cellulose by Gamma-Ray-Irradiation. Cellulose Chem. Technol. (9): 503-511.

Describes a dose dependent effect of radiation on main-chain fractures of cotton.

SHOKOOHIAN, A. 1977. The effect of gamma radiation on different developmental stages of Dermestes maculatus Deg. (Coleoptera: Dermestidae). J. Stored Prod. Res. 13(2): 89-90.

Eggs were highly radiosensitive; at 1 krad about 53% of 6th instar larvae were killed.

SODERSTROM, E. L. 1968. Phototactic response of adults of confused flour beetle and red flour beetle and larvae of black carpet beetle to flashes of blue-white light. J. Econ. Ent. 61(4): 973-75.

Optimum attraction of tenebrionids was 100-15,000 and 200-15,000 flashes per minute; black carpet beetles repelled at 600 per minute.

TILTON, E. W., J. H. BROWER and R. R. COGBURN. 1978. Irradiation disinfestation of cornmeal. J. Econ. Entomol. 71(4): 701-03.

Naturally or artificially infested cornmeal was packed in metal cans and irradiated with gamma irradiation from 15.8 to 62.5 krad. Doses of 35.5 krad or less were inadequate to control Plodia interpunctella, Tribolium castaneum or Rhyzopertha dominica within 1 month but a dose of 15.8 krad resulted in 100% mortality of all stages of all species within 3 months of irradiation. The selected dose must therefore depend upon the desired "quickness" of kill. U.S. Food and Drug Administration regulations allow a range of 20-50 krad.

TILTON, E. W., et al. 1966. Effect of gamma radiation on Trogoderma glabrum and Attagenus piceus. J. Econ. Ent. 59(4): 944-48.

Eggs and larvae of both species were controlled effectively by all dosages; more genetic damage in females.

TUCKER, P. A., S. P. HERSH, G. M. BERRY, N. KERR and D. N. McELWAIN. 1978. Degradation of cellulose with high voltage electrons. Ninth International Congress on electron microscopy, Toronto. Vol. 1 pp. 494-495.

Refers to rates of penetration of cellulose by radiation.

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PART II: SECTION 4

USE OF LOW TEMPERATURE

Insects become inactive at 50°F or below, and if room or store temperatures are kept at this level no insect infestations would progress. However, many insects can remain alive at 50°F and lower, in a kind of dormant state, and if the temperature is raised they will resume their activity. In order to kill most insects, the temperature must be kept at 0°F for one or more days. The egg stage is usually the most difficult to kill with low temperature.

Low temperature sensitivities of many species are given in the notes accompanying references in the bibliography. It is important to realize that the faster the temperature drop is achieved, the more certain the kill. If the temperature falls slowly some insects, including larvae of wood boring beetles, protect themselves by shedding water. This process, which is called purging, leaves only fatty tissue which is not vulnerable to freezing. In general, the faster the freeze rate, the higher the lethal temperature.

Another technique is to lower the temperature and then quickly raise the temperature, and then lower it again, creating a temperature shock effect. This technique often kills insects which would otherwise survive weeks at the lowered temperature (e.g. carpet beetles, clothes moths).

Low temperature treatment is less threatening to wooden objects than heat treatment, but as with heat treatment the relative humidity must be regulated during temperature changes to maintain the moisture content within acceptable limits. Nonetheless, freezing treatments can do irreversible damage to materials with a high moisture content (e.g. certain adhesives).

As with heat treatments and radiation treatments, the use of low temperature poses no risk to people who later handle the items.

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BIBLIOGRAPHY

SECTION 4 - Use of Low Temperature

AREVAD, K. 1975. Control of dermestid beetles by refrigeration.. In: Danish Pest Infestation Laboratory Annual Report 1974. Danish Pest Infest. Lab., Lyngby, Denmark: 41.

Some larvae were able to survive -20°C for up to two hours; most died though in a few minutes.

AREVAD, K. 1980. Dermestid beetles: control by refrigeration. Danish Pest Infest. Lab. Ann. Rep. 1979. pp 64-65.

Adults and pupae of Anthrenus verbasci died after 30 minutes exposure at -20°C. Eggs were killed or failed to produce viable larvae after 2 hours at -20°C. Adults and larvae of A. museorum died after 1 hour's exposure but eggs required 6 hours. One day at -20°C is considered safe for killing all stages of these species.

BACK, E. A. 1935. Clothes moths and their control. USDA Farmers Bulletin 1353.

Larvae of the webbing clothes moth and black carpet beetle can withstand 18°F for a long time. However, refrigeration of infested articles at 18°F for several days, followed by brief exposure at 50°F and then a return to 18°F kills all moth life.

Brushing or beating woolens once or twice a month is very effective against clothes moths, but furs may need to be finely combed or fumigated.

BAKER, J. E. 1983. Temperature regulation of larval size and development in Attagenus megatoma (Coleoptera: Dermestidae). Ann. Entomol. Soc. Am. 76(4): 752-56.

Growth responses of the black carpet beetle were studied at temperatures of 20, 25, 28, 30 and 35°C. Information on larval and pupal size, pupation rates, larval growth phases, and the age at which larvae become sensitive to cooling at 15°C is presented.

BURGES, H. D., et al. 1964. Effect of temperature and humidity on Trogoderma anthrenoides (Sharp) (Coleoptera: Dermestidae) and comparisons with related species. Bull. Ent. Res. 55: 313-25.

CRUMB, S. E. and F. S. CHAMBERLIN. 1934. The effect of cool temperatures on some stages of the cigarette beetle. Florida Entomol. 18: 11-14.

Storage of cigars for 35 days at 55°F gave good control since the eggs do not hatch at this temperature and are non-viable after 35 days when returned to higher temperatures.

HUNTER, A. J. and P. A. TAYLOR. 1980. Refrigerated aeration for the preservation of bulk grain. J. Stored Prod. Res. 16(3/4): 123-31.

The design and development of a refrigerated grain silo capable of maintaining temperature low enough to kill pest insects, less than 10°C.

JAY, E. 1980. Low temperatures: effects on control of Sitophilus oryzae (L.) with modified atmospheres. In: Controlled Atmosphere Storage of Grains by J. Shejbal, Editor. Elsevier Sci. Publ. Co., Amsterdam: 65-71.

From a practical standpoint, there is little need to use modified atmospheres or any other control techniques against Sitophilus oryzae when grain temperatures are below 10.4°C with a mixture of 60% carbon dioxide will give a 99% reduction in 2 weeks and 100% in 3 weeks. Specific data on other mixtures and temperatures are given and discussed.

MULLEN, M. A. and R. T. ARBOGAST. 1979. Time-temperature-mortality relationships for various stored-product insect eggs and chilling times for selected commodities. J. Econ. Entomol. 72(4): 476-78.

Time-temperature-mortality relationships for the eggs of 5 species of stored products pests were investigated. Exposures of 7, 8 and 9 hours, respectively, at -10°C killed 95% of the eggs of Oryzaephilus surinamensis, Tribolium castaneum and Ephestia cautella. Exposures of 28 and 62 hours, respectively, were required to achieve LD95 for the eggs of Callosobruchus maculatus and Lasioderma serricorne. The times required for selected packaged commodities to become chilled throughout were also determined.

SWINGLE, M. C. 1938. Low temperatures as a possible means of controlling cigarette beetle in stored tobacco. USDA Circ. 462.

All stages are killed after 16 days at 36°F and 7 days at 25°F.

TENHET, J. N., et al. 1951. Cold storage to control the cigarette beetle in cigar tobaccos. USDA, Agric. Res. Adm. E-827: 8pp.

Mortality depended on air circulation in the storages and moisture in tobacco.

TENHET, J. N., et al. 1957. Cold storage and cool storage of tobacco to control the cigarette beetle. Tobacco 145(19): 20-25.

Insects killed with five days exposure at 32°F in center of cases of cigar tobacco.

WERMUTH, J. A. 1983. The use of temperature variation to control wood boring insects. Paper presented May 24, Cambridge, Mass. at seminar sponsored by Technol. & Conserv. Magazine at MIT Museum. James Wermuth & Assoc., Newport, RI. 3pp.

A temperature of 125°F for 2½ to 3 hours is lethal to most wood borers. A temperature of -20°F is also lethal and is less threatening to wooden objects than high temperatures. Contains guidelines on minimizing damage from heat or cold treatment of wooden objects.

PART II: SECTION 5

USE OF PARASITES, DISEASES AND PREDATORS

The use of diseases such as *Bacillus thuringiensis* have proved useful in control of outdoor pests such as gypsy moth, but have shown little potential against indoor pests. This is partly because widescale distribution of the disease is more easily achieved in open crop and forest situations than in the subdivided space of buildings. But it is also because exposure of the insect to this and other diseases is achieved through the insect eating crops, trees, etc. which have been coated with sprays of the disease. In a museum context it would not be practical to treat all the items that the insects might feed on because the treatment itself would harm some items. Moreover, to rely on methods which require the insects to eat museum items before they die would result in insect damage to those items.

Parasites and predators have an advantage over diseases because they are capable of independently seeking out their host or prey, whereas a disease would need to be spread by human effort. Parasites showing promise in cockroach control include an Encyrtid wasp, *Comperia merceti,* and a mite, *Pimeliaphilus cunliffei.* The straw itch mite, *Pyemotes tritici*, has caused a high mortality of cigarette beetle eggs in laboratory trials, but the presence of this mite in buildings could be very discomforting to people.

Among the most promising pest predators are spiders, since these catch and kill a wide variety of insects. However, the presence of spiders, wasps and other arthropod predators and parasites poses its own problems. The webbing of spiders is unsightly and the presence of non-web building spiders, such as tarantulas and jumping spiders, may distress some occupants of buildings. Moreover, all these parasites and predators defecate and otherwise mar surfaces, and when they die they leave remains which can sustain museum pests such as carpet beetles.

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BIBLIOGRAPHY

SECTION 5 - Use of Parasites, Diseases and Predators

BRUCE, W. A. and G. L. LECATO. 1979. Pyemotes tritici: potential biological control agent of stored-product insects. In: Recent advances in acarology by J. G. Rodriguez, Editor. Acad. Press, N.Y.: 213-20.

Laboratory trials using the straw itch mite, Pyemotes tritici, as a potential biological control was tested against: Plodia interpunctella (Indian meal moth), Lasioderma serricorne (cigarette beetle), Oryzaephilus mercator (merchant grain beetle), Tribolium castaneum (red flour beetle), and Ephestia cautella (almond moth). P. tritici caused a high mortality of all stages of O. mercator. Mortality of eggs of L. serricorne was approx. 78%. Only 4 and 32% of the larvae and pupae of L. serricorne, respectively, were parasitized. Only 40, 24 and 0% of the eggs, pupae, and adults of T. castaneum were parasitized. Considerable mortality was observed in all life stages of E. cautella and P. interpunctella.

FAUST, R. M. and L. A. BULLA, Jr. 1982. Bacteria and their toxins as insecticides. In: Microbial and viral pesticides by E. Kurstak, Editor. Marcel Dekker, Inc., N.Y.: 75-208.

The use of bacteria and their toxins as insecticides is discussed in terms of mode-of-action, endotoxin and exotoxin activity sites, and genetic manipulation research studies to improve bacteria and their toxins for biological control. A list of insects that are susceptible to the various serotypes of Bacillus thuringiensis is also included.

FIELD, G., L. B. SAVAGE and R. J. DUPLESSIS. 1966. Note on the cockroach mite, Pimeliaphilus cunliffei (Acarina: Pterygosomidae) infesting Oriental, German and American cockroaches. J. Econ. Entomol. 59(6): 1532.

This mite was capable of eradicating laboratory colonies of cockroaches.

FLETCHER, L. W., et al. 1971. A bacterial disease of cigarette beetle larvae. J. Econ. Entomol. 64(6): 1559.

Spore-forming bacillus; culture technique is described.

FRANZ, J. M. 1963. Bibliography of biological control VII. Entomophaga 8(2): 89-161.

More than 1,300 references; biological control by means of entomophagous arthropods and micro-organisms, vertebrate and invertebrate (other than arthropod) enemies of arthropods, biological control of weeds; integrated chemical and biological control of arthropods; includes prey or host index to references.

HENRY, J. E. 1981. Natural and applied control of insects by protozoa. In: Annual Review of Entomology. Volume 26 by T. E. Mittler et al., Editors. Annu. Rev. Inc., Palo Alto, Calif.: 49-73.

Significant progress was made during the past decade on natural and applied control of insects by protozoa. Insights into the mechanisms by which protozoa regulate pest populations are provided along with various research programs which show that this type of biocontrol can be used effectively and efficiently to control pests.

HUNTER, D. K., et al. 1973. The histology and ultrastructure of a nuclear polyhedrosis virus of the webbing clothes moth, Tineola bisselliella. J. Invert. Pathol. 21(1): 91-100.

Polyhedral development was observed in nuclei of cells of the foregut, cardiac valve, midgut, pyloric valve, hindgut, malpighian tubules, ganglia of the ventral nerve cord, muscle, tracheae, fat and hypodermis.

JACKSON, R. H., et al. 1965. Characterization of a cell-free bacterial extract larvicidal to Lasioderma serricorne (cigarette beetle). Biochim. Biophys. Acta 100: 418-25.

KRIEG, A., A. M. HUGER and G. A. LANGENBRUCH. 1983. Bacillus thuringiensis var. tenebrionis, a new pathotype effective against larvae of Coleoptera. A. Angew. Entomol., Hamburg 96(5): 500-08.

A new strain of B.T. was isolated from Tenebrio molitor. This strain was specific to coleopteran species when tested in the lab. The structure of the bacteria is described.

LUTHY, P., J-L. CORDIER and H-M. FISCHER. 1982. Bacillus thuringiensis as a bacterial insecticide: basic considerations and application. In: Microbial and Viral Pesticides by E. Kurstak, Editor. Marcel Dekker, Inc., N.Y.: 35-74.

This history of the development of the Bacillus thuringiensis serotypes including future areas of research for the use of this product as a biocontrol agent. Growth, sporulation, and toxin production is described. The advantages and disadvantages associated with the use of BTI are presented and explained.

McLAUGHLIN, R. E. 1971. Use of protozoans for microbial control of insects. In: Microbial control of insects and mites by H. D. Burges et al., Editors. Acad. Press, N.Y.: 151-72.

Principal types of protozoan pathogens, an evaluation of naturally-occurring protozoan parasite-host relationships, and past attempts at using protozoans as control agents are discussed.

SHAIKH, M. U., et al. 1966. Susceptibility of nine insect species to infection by Bacillus thuringiensis var. thuringiensis. J. Invert. Pathol. 8: 347-50.

Pupation inhibited in mosquitoes: Lepidoptera killed by low dosage; Coleoptera unaffected.

SLATER, A. J. 1984. Biological control of the brownbanded cockroach, Supella longipalpa (Serville) with an Encyrtid wasp, Comperia merceti (Compere). Pest Management 3(4): 14-17.

In research buildings at the University of California in Berkeley, releases of C. merceti have been the primary measure used to control S. longipalpa populations since 1978. Supportive measures, including use of traps, conventional pesticides and habitat modification, were necessary to obtain acceptable control.

TRAMBARULO, A. 1982. Tropical spider devours cockroaches. Pest Control 50(1): 14, 75.

Fifteen banana spiders released in a Florida home appeared to achieve control of 300 German cockroaches within 4 weeks. The spiders are not poisonous to humans, spin no webs and are nocturnal. The researcher speculates that the spiders may release a chemical which attracts cockroaches to them.

TURNBULL, A. L. 1964. The search for prey by a web-building spider, Achaearanea tepidariorum (C. L. Koch). Can. Entomol. 94: 568-79.

The house spider relocates its web until it finds a place where it catches an adequate supply of insect prey.

VAN DER GEEST, L. P. S., et al. 1971. Sources of special materials. In: Microbial control of insects and mites by H. D. Burges, et al., Editors. Acad. Press, N.Y.: 741-49.

Insect species, antisera, mass cultures of pathogens, standard preparations of pathogens, and diagnostic services available from various world laboratories are listed.

WEIDNER, T. 1981. Parasitic wasps may one day control cockroaches. Pest Control Technol. 9(11): 46.

Report on the apparent elimination of brownbanded cockroaches by a parasitic wasp, Comperia merceti, in a campus building at University of California at Berkeley. The wasp biology indicates it has greatest potential for cockroach control in large buildings, such as warehouses. This wasp is specific to brownbanded cockroaches but references are made to other wasps which parasitize Periplaneta species. German cockroaches are not susceptible to this egg parasitizing wasp because the female German cockroach carries her eggs until hatching and this prevents wasp attack.

WRIGHT, V. F., E. DE LAS CASAS and P. K. HAREIN. 1980. Evaluation of penicillium mycotoxins for activity in stored-product Coleoptera. Environ. Entomol. 9(2): 217-21.

The mycotoxins ochratoxin A, citrinin, rubratoxin B, patulin, penicillic acid and oxalic acid were fed to *Tribolium confusum*, *Lasioderma serricorne* and *Attagenus megatoma* in whole wheat flour. Penicillic and oxalic acid were not toxic. Ochratoxin A and citrinin inhibited larval growth of *A. megatoma* but rubratoxin B had no effect. Patulin inhibited growth of *T. confusum*.

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PART II: SECTION 6

MISCELLANEOUS NON-CHEMICAL METHODS

These miscellaneous methods include the following:

- Reducing moisture contents of items and buildings.
- Trapping with sticky traps, light traps or jar traps.
- Screening and caulking pest entry points.
- Sealing or removing pest harborages.
- Physically removing pests, e.g. by vacuum cleaner, brushing.
- Cleaning attractant stains from fabrics, etc.
- Removing or sealing food, garbage, etc. which may sustain pests.
- Use of attractant or repellent lighting.
- Use of ultrasonics.
- Use of low pressure.
- Removing surfaces preferred by pests (e.g. bare wood is liked by German cockroaches).
- Management or policy methods.

Many of these methods might be described as "sanitation" or "maintenance" methods, but they will be more effective if they are more purposefully aimed against pests. For instance, it is good sanitation to wash kitchen floors every night to help deny food to cockroaches and other insects. But it is equally important to dry the floors after washing to help deny them water which they may need more than food.

Dry cleaning of buildings with dusters, brushes and vacuum cleaners should also be conducted with pests in mind. For instance, surface cleaning of visible surfaces may produce an impression of cleanliness; but unless lint is removed from baseboard crevices and from heating or A/C registers in floors and walls an apparently "clean" building can provide a banquet for pests such as clothes moths and carpet beetles. Moreover, cleaning measures must extend beyond the inside of a building to the immediate surrounds. Leaves, bird nests and other debris capable of sustaining or sheltering pests must be regularly removed.

Different insects thrive under different conditions (see earlier sections re. heat and cold parameters) but most thrive better at high humidities than low. Indeed, some pests, such as psocids, can be controlled by keeping humidity below 50%, and wood boring beetles require a certain minimum moisture content of wood and at least some require an air humidity above 60% R.H.

Freeze drying, as a means of dehydrating biological, library, archival and other materials for restoration or conservation purposes, has the spinoff benefit of rendering items less vulnerable to pests with high water requirements. Freeze drying arrests fungal activity, though fungi are not necessarily killed. It is also thought that some insect stages can survive freeze drying (British Museum personal communication), and this seems likely in view of the good survival of sperm when it is freeze dried for long-term storage or transportation. It is worth noting in passing that freeze drying is an excellent example of a technique that was originally developed for other uses, especially in medicine and the food industry, but which now has great value in the museum field.

Screening and sealing can do much to exclude pests from buildings, but the best efforts will be defeated if doors are left open. Moreover, the lower the insect population around a building, the less likely they will invade and become pests. Use of inorganic mulches, non-flowering shrubs and trees, and non-attractant sodium-vapor exterior lighting, will help ensure low outside populations of insects. There is little evidence that ultrasonic devices can exclude insects from buildings and, whenever claims for insect control have been officially challenged, the manufacturers have been forced to withdraw their claims or their devices from the market. (However, there is evidence that ultrasonic devices can aid in rodent control.)

Removing unnecessary wooden surfaces (shelving, packing cases, etc.) can reduce the likelihood of infestation by wood-boring beetles. Removing bare wood also discourages German cockroaches, because they can easily climb it and it retains their aggregation pheromone better than many other surfaces. Some museums are progressively changing the old cork mounts used in insect collections for foam plastic mounts (e.g. Plastozote®) which is less favorable to pests.

Trapping insects is perhaps one of the most underutilized, effective, non-chemical methods, but care must be taken in the selection and placement of traps. For instance, electrocuting light traps can be very valuable in trapping flies indoors, but if placed outside they may attract many more insects than they kill and result in worse pest problems. Traps can be used both to achieve control (though this is unlikely to be practical against most pests) and for monitoring the types and locations of pests (this is a very valuable role). Regular checking of traps can indicate when an infestation began and hence provide a clue to the origin of the infestation.

Management or policy methods of minimizing pest problems include quarantining suspect collections, designating areas where food may be eaten (or not eaten) by staff and ensuring that kitchen supplies come from sources subject to rigorous pest control programs. In addition, in each department or section, there should be a logbook for recording not only pest sightings but conditions conducive to pests (such as a sanitation problem).

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BIBLIOGRAPHY

SECTION 6 - Miscellaneous Non-chemical Methods

including cleaning, trapping, screening, drying, ultrasonics and pressure changes.

APT, A. C. 1955. A study of the role of vacuum cleaning in the control of insects in flour mills. Milling Prod. 20(8): 5-7.

Probable that vacuum cleaning alone would control insect populations in average mill for several months.

BALLARD, J. B. and R. E. GOLD. 1982. Ultrasonics - no effect on cockroach behavior. Pest Control 50(6): 24, 26.

Neither sonic nor ultrasonic frequencies were effective in repelling or controlling the German cockroach (Blattella germanica).

BARAK, A. V., M. SHINKLE and W. E. BURKHOLDER. 1977. Using attractant traps to help detect and control cockroaches. Pest Control 45(10): 14-16, 18-20.

Oriental cockroaches were more easily controlled with traps than German cockroaches. The availability of numerous cracks and crevices reduced trapping effectiveness.

BURGESS, N. R. H., S. N. McDERMOTT and A. P. BLANCH. 1974. An electrical trap for the control of cockroaches and other domestic pests. J. R. Army Med. Cps. 120: 173-175.

12,000 German cockroaches caught in a hospital canteen in one year.

CALDERON, M., et al. 1968. Sensitivity of three stored-product insect species exposed to different low pressures. Nature, London. 218(5137): 190.

The highest percentage of mortality occurred at the lowest pressures and mortality decreased with increasing pressures.

DAY, M. F., et al. 1963. Physical injuries. In: Insect Pathology. An advanced treatise. Volume I. Acad. Press, N.Y.: 29-63.

The effects of gravity increases, percussion, mechanical stimulation, air pressure changes, temperature extremes, sound, high-frequency electric fields, irradiation, and wounds are discussed with examples taken from various insect groups.

EBELING, W. and D. A. REIERSON. 1974. Bait trapping silverfish, cockroaches and earwigs. Pest Control 42(4): 24, 36-39.

Empty jar traps may catch as many insects as jars baited with food attractants. Correct positioning of traps is the most important element in trapping.

FARMER, B. R. and W. H. ROBINSON. 1984. Is caulking beneficial for cockroach control? Pest Control 52(6): 28, 30, 32.

Caulking crevices achieved little improvement in German cockroach control in apartments. The authors conclude that where sanitation is better caulking crevices may be more beneficial. However, in some situations it may be best to leave crevices uncaulked and therefore accessible to the injection of insecticides.

HINTON, H. E. 1943. Natural reservoirs of some beetles of the family Dermestidae known to infest stored products, with notes on those found in spider webs. Proc. R. Entomol. Soc. London (A) 18: 33-42.

HENNEBERRY, T. J. 1971. Nonchemical methods of insect control. In: Study book for the introductory training course pesticides and public health. EPA Div. Pestic. Commun. Stud., Chamblee, Ga.: 63-78.

Resistant plant varieties, irradiation sterilization, chemosterilization, use of pathogens and parasites, attractants, repellents, hormones, and cultural techniques are all briefly discussed as insect control techniques.

HOFFMANN, C. H. 1971. Future trends in entomology. Nat. Pest Contr. Oper. News 31(9): 6-7, 9-10, 13-15.

A general discussion of USDA projects in the areas of biocontrol, insect sterility, plant resistance, cultural and mechanical control, attractants, and hormones is presented. Integrated control is also discussed.

IMAMURA, S. 1935. On the olfactory and visual senses of Anthrenus verbasci (L.) Bull. Seric. Exp. Sta. Japan 9(1): 1-21.

Adults are attracted to blue and white colors.

Note by KOS: this could perhaps be exploited in trapping programs or in reducing outside populations on ornamentals (they are common on Spiraea).

KARDATZKE, J. T., I. E. RHODERICK and J. H. NELSON. 1981. How roach surveillance saves time, material, and labor. Pest Control 49(6): 46, 47.

Substantial savings in manpower and pesticides resulted from use of sticky traps as monitoring tools at Fort Detrick.

KAWAHARA, S. 1960. The influences of relative humidity upon the growth and reproduction of the casebearing clothes moth, Tinea pellionella (L.). Botyu-Kagaku 25(2): 78-84.

75% relative humidity is the most favorable.

KNULLE, W. and R. R. SPADAFORA. 1969. Water vapor sorption and humidity relationships in Liposcelis (Insecta: Psocoptera). J. Stored Prod. Res. 5: 49-55.

L. knullei died within one week at all humidities below their critical level and L. bostrychophilis died after 10 days. Reducing building humidity below 50% will help control psocids.

LINSLEY, E. G. 1944. Natural sources, habitats, and reservoirs of insects associated with stored food products. Hilgardia 16(4): 187-214.

Reservoirs of clothes moths and carpet beetles include felt-like accumulations behind baseboards, under door jambs, treads, etc. and bird nests.

LINSLEY, E. G. 1946. Some ecological factors influencing the control of carpet beetles and clothes moths. Pests 14(7): 10, 12, 14, 16, 18.

Natural habitats of carpet beetles and clothes moths include nests of birds, rodents, bees, hornets, mud daubers and spiders. These should be destroyed before the onset of cool weather which may drive the insects indoors.

MALLIS, A., A. C. MILLER and R. C. HILL. 1959. The attraction of stains to three species of fabric pests. J. Econ. Entomol. 52: 382-84.

Larvae of the webbing clothes moth and young larvae of the black and furniture carpet beetles are attracted to common stains, e.g. sweat, urine, tomato juice, milk, coffee and beef gravy because of the salt they contain. Older larvae of the furniture carpet beetle are less attracted and older larvae of the black carpet beetle are not attracted at all.

MERRILL, E. D. 1948. On the control of destructive insects in the herbarium. J. of the Arnold Arboretum 29: 103-110.

Effective control of cigarette beetles in herbaria by trapping gravid females on preferred plants placed strategically. The plant traps were periodically disinsected and put back.

MOORE, W. and T. GRANOVSKY. 1984. Interpreting cockroach stick trap counts. Pest Control Technol. 12(10): 64, 66, 71, 72.

Sticky traps catch some species of cockroach more than others but in the tests reported no species is reduced to a level approaching that of an effective chemical treatment. Guidelines are given on how best to use traps. By pinpointing infestations, identifying entry points and measuring population changes, traps can be used to reduce labor and pesticide use in control programs.

NAVARRO, S., et al. 1972. Exposure of Ephestia cautella (Wlk.) (Lepidoptera: Phycitidae) to low pressures: effects on adults. J. Stored Prod. Res. 8(3): 209-12.

Adult life was shortened at all reduced pressures; at 100 mm hg all adults died in 14 hours. Oviposition was affected.

NIXON, J. 1984. Novel approaches often whip occasional invaders. Pest Control 52(4): 44-46.

Brief review of various non-chemical methods of discouraging occasional invaders (e.g. millipedes, sowbugs, groundbeetles and spiders). Methods include drainage control, limitation of ground cover and other pest harborages, sealing of entry points and use of non-attractant lighting.

RAWSTHORNE, J. 1983. The facts about ultraviolet flying insect control. Proc. 6th Brit. Pest Control Conf. Cambridge. Paper No. 17. 11pp.

Reviews history and current uses of light traps, focusing on fly control in food plants. (Note: many museum pests, e.g. clothes moths, are not attracted to light traps.)

REED, W. D., E. LIVINGSTONE and A. W. MORRILL, Jr. 1934. Experiments with suction light traps for combating the cigarette beetle. J. Econ. Entomol. 27: 796-801.

Satisfactory control obtained by operating the trap at sunset, the period of activity and migration of adults.

SPILLER, D. 1949. Effect of humidity on hatching of eggs of the common house borer, Anobium punctatum. Rev. Appl. Entomol. A. 38(6): 263.

No eggs hatched or hatching was impaired at humidities below 60%.

VINZANT, J. P. and W. D. REED. 1941. Type of wire screen required for excluding cigarette beetles and tobacco moths from warehouses. J. Econ. Entomol. 34(5): 724.

Eighteen or 24 mesh screens are necessary to keep beetles out.

WILSON, H. F. 1940. Lures and traps to control clothes moths and carpet beetles. J. Econ. Entomol. 33: 651-53.

Clothes moths and carpet beetles are attracted into box traps containing cloth pads treated with fish meal or an alcoholic extract of fish meal. Sticky fly papers treated with various animal substances attract adults and feeding larvae.

WOJCIK, D. P. 1968. Tests for audible and ultrasonic sound production by stored-product insects. J. Econ. Entomol. 61(5): 1414-17.

Technique and equipment tested on tenebrionids, cucujids, curculionids, dermestids and pyralids.

WOODROFFE, G. E. 1953. An ecological study of the insects and mites in the nests of certain birds of Britain. Bull. Entomol. Res. 44(4): 739-772.

The varied carpet beetle Anthrenus verbasci is commonly found in sparrow nests.

WRIGHT, C. G. 1966. Modification of a vacuum cleaner for capturing German and brownbanded cockroaches. J. Econ. Entomol. 59(3): 759-60.

Method for catching live cockroaches.

PART II: SECTION 7

USE OF CONVENTIONAL INSECTICIDES AND FUMIGANTS

Conventional insecticides and fumigants should not be too readily dismissed in favor of non-conventional or low toxicity pesticides (e.g. new pyrethroids) or non-chemical methods (e.g. heat, cold, gamma radiation). After all, at one time all these conventional insecticides were considered to be new, and many were considered to be non-conventional and low in toxicity compared with older remedies such as lead arsenate, hydrogen cyanide, strychnine and mercury compounds. However, familiarity breeds contempt and, in addition, in the case of pesticides it seems the more we learn about them the more we fear them. Often these fears become exaggerated as a result of poorly conducted toxicity tests or media efforts to profit from human gullibility regarding "facts" about risks from pesticides, coffee, barbecued beef, saccharin, etc.

Concerns about pesticides and other chemicals need to be weighed against other facts. For instance, despite (or perhaps because of) our greater exposure to chemicals, we are living longer. And despite the focus on cancer risks, with the exception of lung cancer, all forms of cancer are declining if assessed on an age-weighted basis (in other words, we have to take into account the fact that the incidence of cancer rises with increasing age, so you would expect an aging population to have more cancer than a younger population).

Another factor to be weighed is that it is impossible to prove that a chemical is not harmful. So instead of thinking of new chemicals such as pyrethroids, chitin inhibitors, pheromones, etc. as being harmless, we should instead think that they have not yet been proved harmful in terms of carcinogenicity, mutagenicity, teratogenicity, etc.

Many professionals involved in pest control would much rather work with products which have a long history of use and for which we have a lot of information on advantages and disadvantages, than work with products about which little is known. In this sense, a product such as chlordane (or lindane) can be likened to aspirin. They both are effective, they both have known disadvantages, but on balance their benefits outweigh the known disadvantages.

Regarding the safety of conventional insecticides and fumigants, the most convincing evidence for their safety in actual use (as opposed to their safety if applied in megadoses to sensitive strains of laboratory animals) comes from epidemiological investigations. Recently, the Department of Epidemiology of the Harvard School of Public Health conducted an epidemiological investigation of the health of pest control workers who had long-term exposure (mostly 20 years or more) to conventional insecticides, including chlorinated hydrocarbons (especially chlordane), organophosphates and carbamates. The study involved 16,000 people, all of whom were more exposed to conventional pesticides than any other sector of society. The report by Dr. Brian MacMahon, professor and chairman of the department, concluded that "no pattern has been revealed that would be suggestive of a relationship between employment as a pest control operator and increased risk of any particular health hazard. Neither do applicators whose intensity of exposure was believed to be the highest, or those employed as termite control operators, with their higher likelihood of exposure to chlordane, show any such pattern."

Despite the excellent safety record of pesticides used in buildings, it is good practice, as well as common sense and Federal and state law, that all pesticides be used in a manner consistent with their labeling. There should be no presumption of safety if a pesticide is misused, not even if the pesticide is a so-called "safe" pesticide. Less than a half teaspoon of boric acid powder can kill a child, yet this material is commonly promoted as being safe. Nor should there be any assumption that "natural" insecticides such as pyrethrum are safer than synthetic insecticides. Indeed, pyrethrum has a worse safety record than any other insecticide in terms of the number of people hurt by it. This is because a significant proportion of the population shows various degrees of allergy to pyrethrum, ranging from sneezing to anaphylactic shock. Moreover, pyrethrum has been shown to cause liver microsomal enzyme induction, and even it has not escaped accusations of being a carcinogen!

In Part I, outline recommendations for control of each pest were given. These included use of chlorinated hydrocarbons (lindane, pentachlorophenol), organophosphates (chlorpyrifos, diazinon, dichlorvos, propetamphos, etc.) and carbamates (bendiocarb, carbaryl, propoxur). These have acute oral toxicities (LD50s) to rats in the range 50 to 300 mg/kg. This compares with caffeine which has an LD50 of 192 mg/kg. Whatever the known toxicities of pesticides it is prudent to avoid unnecessary exposure to them. This can be done by focusing attention on treating places which are not subsequently contacted by people. So instead of just applying residual insecticides to exposed surfaces, they should primarily be applied in cracks and crevices, wall voids and other hidden areas. This has the added advantages of putting them where the pests hide and minimizing their degradation by cleaning measures or ultraviolet light. A further advantage is that, because such "hidden" applications last longer, there will be less frequent need for repeat applications with their attendant risks.

Where applications in exposed areas are necessary to deal with a particular pest, there should be an effort to choose products which are readily metabolized and excreted from the human body. An example would be carbamates, such as bendiocarb, which are metabolized and excreted by humans even faster than pyrethrum, and without any allergic reactions.

Regarding fumigants, they are all biocides, in other words capable of killing all forms of life as acute poisons. Regarding risks of chronic toxicity, there is a growing body of evidence from laboratory tests that some fumigants, such as ethylene oxide, are mutagenic and carcinogenic. However, the author is not aware of any evidence that such effects have arisen in humans from practical uses of these fumigants. What is more certain is that conventional fumigants are capable of harming various materials that might be found in museum collections. The following are examples of fumigants and vulnerable items in museums:

FUMIGANT:	SOME VULNERABLE ITEMS IN MUSEUMS:
1. Methyl bromide	■ Sponge rubber, foam rubber, reclaimed rubber. ■ Furs ■ Horsehair ■ Feathers ■ Leather (esp. sulfur tanned leather). ■ Woolens ■ Viscose rayon ■ Vinyl ■ Paper (esp. photographic prints & blueprints). ■ Cellophane
2. Phosphine	■ Brass ■ Copper ■ Gold ■ Silver
3. Ethylene oxide	■ Leather ■ Wet paper ■ Paint and varnish

In addition, DDVP or dichlorvos is sometimes used as a fumigant but it is corrosive to mild steel, brass, silver, tin and lead, and it changes the color of certain synthetic dyes used in carpets. Nonetheless, it can be useful in exhibit cases not containing vulnerable items, in the form of impregnated vinyl strips. A mixture of ethylene dibromide and carbon tetrachloride (Dowfume® 75) is relatively safe on collections, but it is not a good penetrant of wood for control of beetles belonging to the genus *Lyctus*. Sulfuryl fluoride has perhaps the best reputation in terms of safety to materials and broad spectrum efficacy (it has excellent penetrating abilities). However, there is little definitive information about the minimum dose rates which are effective against particular stages of particular pests.

BIBLIOGRAPHY

SECTION 7 - Use of Conventional Insecticides & Fumigants

ANONYMOUS. 1965. Borers in houses (insects attacking seasoned timber). Tasmanian J. Agric., Hobart 36(2): 120-23.

Briefly covers biology of the wood boring beetles, timber or wood attacked, and preventative and control measures.

ANONYMOUS. 1970. The furniture beetle: what can the U.S. expect? Pest Control 38(3): 62-65.

Controlled with 1% lindane oil solution.

ANONYMOUS. 1972. Anobiid powder post beetles. NPCA Tech. Rel. 21-72. 5pp.

Identification of beetle species, their damage, and their distribution, habits and control recommendations.

ANONYMOUS. 1979. Danish Pest Infestation Laboratory Annual Report 1978. Danish Pest Infest. Lab., Lyngby, Denmark: 98pp.

Highlights of this annual report are noted. Bioallethrin vaporizing mats were effective in controlling mosquitoes in rooms. Vitamin B-1 was discounted as a mosquito repellent. Various insecticide formulations were tested against houseflies and cockroaches. Resistance tests are reported. A Pharaoh's ant infestation of a large shopping center was controlled with bendiocarb. Some stored product pest problems are mentioned. Rat and mouse control formulations of anticoagulants were tested.

ANONYMOUS. 1979. Ficam W and Dust protects rare materials - Hawaii's Bishop Museum gets pest protection. Insectimes 2(4): 4. NOR-AM Chemical Corp. (formerly Fisons, Inc.), Wilmington, Del.

Reports the successful use of Ficam W and Ficam D against cigarette and museum beetles in the Herbarium Pacificum collection.

ANONYMOUS. 1981. The webbing clothes moth. Pest Control 49(12): 56.

Brief review of biology and control methods. Reduction of moths food and harborage is recommended as a preliminary to using pesticides. Pesticides recommended include sprays of 0.5% Dursban, 1% diazinon, 2% malathion. Sprays of DDVP, Baygon, Knox Out, Safrotin and Sectrol are also recommended. For wall and floor voids and inside furniture, dust formulations of diazinon and malathion are suggested. The article does not mention some other effective products such as Ficam and resmethrin.

ARCHER, W. A. 1952. Aerosol for controlling herbarium pests. Science 116 (3009): 233-234.

A pyrethrum and DDT aerosol controlled herbarium pests, including psocids.

AREVAD, K. 1977. Evaluation of methods for protection of bird skins against attack by insects. In: Danish Pest Infestation Laboratory Annual Report 1975. Danish Pest Infest. Lab., Lyngby, Denmark: 20.

Of the tested materials only dieldrin managed to keep skins undamaged when used inside only; the most efficient insecticidal effect was obtained by spraying the surface with a 20% solution of lindane.

ASHMAN, F., D. J. WEBLEY and N. Z. ACHILLIDES. 1974. Space treatment of warehouses using dichlorvos. Bull. Org. Eur. Mediterr. Prot. Plant 4(4): 429-45.

Effective control of Ephestia cautella was obtained by using Shell Vapona pest strips at 2 strips/100 cu cm or by daily spraying of dichlorvos at 10 g/1000 cu cm.

BACK, E. A. 1939. Bookworms. Smiths Inst. Ann. Rept. 365-74.

Use of a mixture of ethylene oxide and carbon dioxide in vacuum vaults effectively controls beetles in books at the National Archives.

BAJOMI, Dr. 1981. Budapest experiment on cockroach control. International Seminar on Cockroach Control, Budapest, Oct. 19-23, 1981.

Dr. Bajomi of the Babolna Pest Control Unit in Budapest reported on the successful control of cockroaches in 8,000 apartments. The treatment involved professionally applied residual insecticides and pyrethroid aerosols used by homeowners. Ficam (bendiocarb) was the preferred residual insecticide.

BAKER, J. M., et al. 1967. The toxicity of tributyltin oxide to the wood-boring beetles Lyctus brunneus Steph. and Anobium punctatum (DeG.). Ann. Appl. Biol. 60(2): 181-90.

A 0.5% solution of tributyltin oxide applied to wood gave almost complete protection against L. brunneus. TBTO with white spirit was more effective against A. punctatum than was TBTO with benzine.

BAKER, J. M., and E. C. HARRIS. 1969. Tests with dichlorvos against the common furniture beetle Anobium punctatum (DeG.). Int. Pest Control 11(4): 17-23.

Dichlorvos vapor prevented adults from emerging from infested wood and subsequent re-attack.

BATTH, S. S. 1971. Influence of temperature on the effectiveness of paradichlorobenzene fumigation of webbing clothes moth larva. J. Econ. Entomol. 64(4): 989-90.

Nearly all moth larvae were killed in air-tight containers with PDB fumigation in 4 days at 32.2°C, 6 days at 26.7°C, 9 days at 21.1°C, and in 13 days at 15.5°C.

BATTH, S. S. 1972. Evaluation of vinyl garment bags as chambers for paradichlorobenzene fumigation of fabric-insect pests. J. Econ. Entomol. 65(4): 1074-80.

Twelve brands of vinyl garment bags were evaluated as chambers for PDB fumigation of larvae of the webbing clothes moth and the black carpet beetle. Brand names are not given.

BAXTER, H. O., V. R. COLEMAN and R. E. MOTSINGER. 1979. Wood preservation and wood products treatment. EPA Off. Pestic. Programs, Wash., D.C.: 20pp.

This guide provides information for commercial applicators on recognition of wood pests and damage, methods of control and environmental and safety precautions. Pests discussed include drywood and subterranean termites, ants, fungi, beetles, marine borers, shipworms, limnoria, pholads and flathead borers.

BECKER, G. 1962. The efficacy of isomers of BHC against wood-destroying beetle larvae. Anz. Schadlingsk. 35(7): 97-99.

Alpha isomer most effective against Anobium punctatum in lab tests with HCH impregnated wooden blocks.

BECKER, G., et al. 1969. Recent research work on diodeterioration of materials in Berlin-Dahlem. Int. Biodeterior. Bull. 5(3): 125-33.

Soft-rot fungi, house longhorn beetle, termites, marine borers, wood preservation, methods.

BENGSTON, M. 1976. Timed daily emission of dichlorvos for control of Ephestia cautella (Walker) infesting stored wheat. J. Stored Prod. Res. 12(3): 157-64.

A dichlorvos aerosol emission system gave control of both naturally occurring and caged populations of Ephestia cautella superior to that given by slow release dichlorvos strips in wheat storage.

BENNETT, G. W. and E. S. RUNSTROM. 1979. New developments in pest control insecticides. Pest Control 47(6): 14-16, 18, 20.

Several new formulations were evaluated in laboratory and field tests against German cockroaches, house flies and various stored product pests. The insecticides used included new formulations of Ficam, resmethrin, sectrol, permethrin, Dursban and Sevin. Results are given of individual tests, some shelf life data is included.

BERNHARD, K. M. and G. W. BENNETT. 1981. Ultra-low-volume applications of synergized pyrethrins for stored-product insect control. J. Econ. Entomol. 74(5): 572-76.

This lab study evaluated the interaction of harborage and exposure time on the control of Sitophilus oryzae and Tribolium confusum using ULV applications of synergized pyrethrins. ULV treatments were most effective immediately after application. Insects exposed 15 minutes after application were not effectively controlled. ULV treatments did not penetrate well into completely enclosed spaces.

BLETCHLY, J. D., et al. 1961. Methods of testing preservatives against the common furniture beetle [Anobium punctatum (DeG.)] and house longhorn beetle [Hylotrupes bajulus (L.)] at the Forest Products Research Laboratory. J. Inst. Wood Sci. No. 8: 4-11.

BOLES, H.P., R. E. BRY and L. L. McDONALD. 1974. Dichlorvos vapors: toxicity to larvae of the furniture carpet beetle. J. Econ. Entomol. 67: 308-09.

DDVP resin strips effective after 24 hours exposure.

BOOCOCK, D. 1973. Why we preserve wood, an inherently durable material. Int. Pest Contr. 15(5): 25-26.

Review of several papers. Lindane prevents emergence of Anobium punctatum.

BORLUND, H. P., et al. 1970. Observations on dichlorvos. In: Danish Pest Infestation Laboratory Annual Report 1969. Danish Pest Infest. Lab., Lyngby, Denmark: 33.

Dichlorvos controlled flying adult clothes moths and Ephestia elutella but not their larvae. A double-dosage of strips in an unventilated warehouse room completely failed to control Dermestes lardarius or Ptinus tectus.

BRY, R. E. 1975. Synergized pyrethrins as a short-term protectant of woolens against larvae of the black carpet beetle (Coleoptera: Dermestidae). J. Ga. Entomol. Soc. 10(1): 14-17.

Treatment with pyrethrins + piperonyl butoxide satisfactorily protected the cloth initially and through 6 months of aging.

BRY, R. E. 1980. Protecting woolens against clothes moths and carpet beetles. USDA Home Garden Bull. No. 113: 8p.

A USDA report which provides an overview of the clothes moth and carpet beetle as pests of fabrics. Included are graphic descriptions with information on their biology and habits. Protective treatments and moth proofing are also described.

BRY, R. E., et al. 1960. Preliminary evaluation of lindane and heptachlor crystals for protection of crated furniture against insect damage. J. Econ. Entomol. 53(5): 966-67.

Adhered crystals more effective than bagged crystals.

BRY, R. E., et al. 1969. Gardona as a mothproofer of woolen fabric. J. Econ. Entomol. 62(4): 868-72.

Deposits as low as 0.001% by weight protected against damage by Attagenus megatoma and Tineola bisselliella.

BRY, R. E., et al. 1972. Pyrethrins for the protection of rayon thread from damage by cigarette beetle larvae. J. Ga. Entomol. Soc. 7(3): 218-20.

Protection was obtained by application of 0.07% by weight of pyrethrins.

BRY, R. E., et al. 1977. Long-term protection of woolen fabric with synergized pyrethrins. Pyrethrum Post 14(1): 26-29.

Oil-based aerosols or aqueous pressurized sprays applied to woolen cloth protected the cloth against damage by larvae of *Attagenus megatoma* and *Tineola bisselliella*, even after the treatments had aged 27 months.

BRY, R. E., et al. 1979. Spray applications of permethrin against fabric pests. Pest Control 47(4): 14-17.

The data presented in this paper suggests that permethrin is an effective fabric protectant for at least 6 months when it is applied to woolen cloth as an oil aerosol or as an aqueous pressurized spray. The test insects were the black carpet beetle and the webbing clothes moth.

BRY, R. E., et al. 1980. Pyrethroid combination sprays effective as fabric protectant. Soap Cosmet. Chem. Spec. Mar: 5p.

Results of research to determine the effectiveness of sumithion plus neopynamin formulations sprayed on woolen cloth for protection against damage by larvae of the black carpet beetle, the furniture carpet beetle, and the webbing clothes moth.

BRY, R. E. and J. H. LANG. 1974. Efficacy of pyrethrins as a protectant for woolens against larvae of the black carpet beetle, *Attagenus megatoma* (F.). Pyrethrum Post 12(3): 119-20, 122.

Woolen cloth was protected for up to 6 months by an application of 0.05% pyrethrins and pyrethrins plus piperonyl butoxide.

CHILDS, D. P. 1966. Laboratory evaluation of insecticides against the cigarette beetle. J. Econ. Entomol. 59(4): 846-49.

Gives effectiveness as a residual and vapor toxicant; least toxic were DDT, pyrethrum, piperonyl butoxide and carbaryl.

CHILDS, D. P., et al. 1966. Control of the cigarette beetle in tobacco warehouses with automatic dichlorvos aerosol treatments. J. Econ. Entomol. 59(2): 261-64.

Daily automatic releases of 0.47g/1000 cu ft with 16 hr exposures gave 100% mortality to caged adults.

CHILDS, D. P., et al. 1970. Phosphine fumigation of tobacco in louvered warehouses. Tobacco, N.Y.: 170(14): 21.

Phosphine (PH3) was found to be a very effective fumigant to protect tobacco in hogsheads against the cigarette beetle, *Lasioderma serricorne* (F.) in louvered tobacco warehouses.

CHILDS, D. P., et al. 1971. Phosphine fumigation of tobacco in freight containers: I. Tobacco, N.Y.: 172(1): 33-36.

Tobacco in freight containers was fumigated with 165 aluminum phosphide pellets/1,000 cu ft in an effort to control *Lasioderma serricorne*. Aeration of phosphine from the tobacco required 48 to 72 hours.

CHILDS, D. P., et al. 1971. Phosphine fumigation of tobacco in freight containers: II. Tobacco, N.Y.: 172(1): 37-38.

165 phosphide pellets gave good control of the cigarette beetle, Lasioderma serricorne, although smaller dosages proved ineffective.

COGBURN, R. R., et al. 1963. Use of phosphine for fumigating against stored grain insects. Grain Age: 1p.

Effective but will cause corrosion of copper.

COLEMAN, G. R. 1979. British Wood Preserving Assn. News Sheet No. 155, May.

Control of powder post beetles by lindane is partially attributed to repellency preventing adult emergence from infested wood which has been treated.

CORNWELL, P. B. 1976. The cockroach. Vol. II. Hutchinson, London. 557 pp.

Exhaustive review of cockroach control up to 1972, mostly using conventional pesticides. 921 references.

CROSS, D. J. 1976. Persistence of organochlorine insecticides in wood after 25 years. Mater. Org., Berlin 11(2): 145-57.

A study of the effectiveness of various insecticides in preventing attack by Anobium was conducted in 1952 by treating kahikatea blocks with dieldrin, gamma-HCH, DDT, or DDD at various concentrations. The persistence of these pesticides over 25 years and possible impact of house and timber treatment in urban areas are discussed.

CYMOREK, S., et al. 1964. Testing of wood preservatives on their effectiveness in the control of Anobium punctatum (De Geer). Holz Als Roh-U. Werkst. 22(8): 304-08.

DURHAM, W. F., et al. 1959. Toxicological studies of O,O-dimethyl-2,2-dichlorovinyl phosphate (DDVP) in tobacco warehouses. AMA Arch. Indust. Hlth. 20: 202-10.

Concentrations of 0.7 micrograms per liter have been withstood by men, monkeys and rats for 1 hour without effect on blood cholinesterase. Low dosages of DDVP applied as aerosol in warehouse present no hazards to workers.

EHMANN, N. R. 1961. A new method for control of powder post beetles. Pest Control 29(6): 42, 46, 46b.

Two to three pounds of methyl bromide per 1,000 cu ft, confined for 24 to 48 hours, will eliminate house infestations.

EVANS, B. R., et al. 1965. The incidence, importance, and control of insects found in stored food and food-handling areas of ships. J. Econ. Entomol. 58(3): 479-81.

Inspection of 1428 ships revealed B. germanica and P. americana most important pest in galley and mess rooms. Control focused on using conventional chemicals.

FREY, W. 1939. Ueber die wirksamkeit von naphthalin, paradichlorobenzol und hexachlorathum als kliedermottenbekamp fungsmittel. Arb. Physio. Angew. Ent. Berlin 6: 189-198.

Naphthalene, at a dose of 15 ounces per 100 cu ft and at 68°F to 73°F killed 40% of Tineola bisselliella larvae in 15 days, 100% of adults in 5 days and 99.6% of eggs in 4 days. Paradichlorobenzene at the same rate and temperature killed 100% of larvae in 4 days, 100% of adults in one day and 100% of eggs in 4 days.

FUNDER, J. V. 1969. Testing of insecticides in the laboratory. Insecticides for fly control. Insecticides against clothes moth larvae. Insecticides against granary weevils (Sitophilus granarius). In: Government Pest Infestation Laboratory Annual Report 1968. Danish Pest Infest. Lab., Lyngby, Denmark: 25-27.

Aerosols of 0.2% pyrethrins + 1.2% piperonyl butoxide + 5% strobane or + 4.80% perthane and 0.4% pyrethrins + 2.4% piperonyl butoxide + 5% methoxychlor were tested against clothes moth larvae and flies. Knockdowns with the above formulations were poorer than with the standard fly aerosol. Only the methoxychlor aerosol gave good residual control of moth larvae. Wettable powder formulations of fenthion gave better control of flies than did similar formulations of trichlorfon. Various formulations of phthalthrin powder were tested against Sitophilus granarius.

GILLENWATER, H. B., et al. 1971. Dichlorvos applied as a vapor in a warehouse containing packaged foods. J. Stored Prod. Res. 7(1): 45-56.

More effective against Tribolium confusum adults than against larvae of Attagenus megatoma. A safe, effective space treatment for use in food storage areas.

GIRISH, G. K., et al. 1972. Studies on the behaviour of ethylene dibromide and carbon tetrachloride mixtures: II. Bull. Grain Technol., Hapur 10(1): 30-36.

A mixture of ethylene dibromide and carbon tetrachloride gave the best control of stored product Lepidoptera and Coleoptera when compared to aluminum phosphide or ethylene dibromide alone.

HAGMAN, L. E. 1982. Ant baits - tests with borax material show strong acceptance. Pest Control 50(5): 30, 32.

Baits containing 5.4% borax controlled the three most common house foraging ants, the pavement ant, thief ant and little black ant.

HAREIN, P. K., et al. 1971. Dichlorvos space treatment for protection of packaged flour against insect infestation. J. Stored Prod. Res. 7(1): 57-62.

Effectively prevented dispersal of insects from infested to uninfested bags of stored flour.

HARRIS, E. C., et al. 1970. Dichlorvos strips for furniture beetle control: A field trial. Int. Pest Control 12(4): 28-33.

Adults and eggs of Anobium punctatum killed; also protected against initiation of attack.

KARDATZKE, J. T., D. P. DRIGGERS and J. H. NELSON. 1982. Fogging plus residuals counter harborage effects. Pest Control 50(5): 53, 56.

Because of cockroaches' ability to avoid insecticide fogging by hiding, fogging should be accompanied by a residual spray to achieve sufficient control.

KENAGA, E. E. 1957. Some biological, chemical and physical properties of sulfuryl fluoride as an insecticidal fumigant. J. Econ. Entomol. 50(1): 1-6.

Article includes reassurances that sulfuryl fluoride shows no observable reaction with metals, rubbers, plastics, paper, leather, cloths, wallpaper and many other household items, based on odor, color or corrosive changes.

Results against various life stages of 14 insect species are reported in which the LD_{95} varied from 0.65 ounces per 1,000 cu.ft. against lesser grain borer adults to 75.8 ounces per 1,000 cu.ft. against eggs of the black carpet beetle. While all insect stages can be killed by sulfuryl fluoride, adults, pupae and larvae are more susceptible than eggs. Performance was generally better than methyl bromide.

KIRKPATRICK, R. L. and H. B. GILLENWATER. 1981. Toxicity of selected insecticidal aerosols, dusts and sprays to two species of stored-product insects. J. Ga. Entomol. Soc. 16(2): 175-180.

Confused flour beetle adults, Tribolium confusum, and black carpet beetle larvae, Attagenus megatoma, were exposed to 14 promising insecticides applied as aerosols, dusts, or sprays in truck vans. A formulation of chlorpyrifos applied with a spinning disk applicator produced the highest level of control of these two species of stored-product insects.

KOULA, V. and J. OLIBERIUS. 1975. Smoke aerosols with organophosphates in the control of pests in closed rooms. Sb. Ustav Vedeckotech. Inf. Ochr. Rostl., Prague 11(2): 103-10.

The use of dichlorvos, fenitrothion, and malathion can replace chlorinated insecticides for control of Tribolium confusum, Calandra granaria, Tenebrio molitor, Musca domestica, and Ephestia kuehniella in closed rooms.

KOZLOV, V. I. and M. E. LOGINOVSKII. 1973. Control of dermestid beetles in fur and leather raw materials storehouses. Veterinariya, Moscow 10(Oct): 47-48.

LANG, J. H., R. E. BRY and R. E. BOATRIGHT. 1976. Organophosphorus insecticides as potential wool protectants. Soap Cosmet. Chem. Spec. (Sep): 3p.

Of nine candidate insecticides evaluated against dermestid damage the most effective was chlorpyrifos.

LONG, T. 1984. Toxicity and hazards of pesticides. Pest Management 3(2): 24-34.

Useful review of the relative toxicities of common pesticides and the mode of toxic action of the main insecticide groups. Warns against undue reliance on LD50 figures as a measure of likely hazard. Good recommendations on reducing pesticide exposure.

LONGONI, A. and G. MICHIELI. 1969. Initial and residual activity of Cidial (phenthoate) compared with that of malathion and lindane on insects affecting stored products. J. Econ. Entomol. 62(6): 1258-61.

Cidial has high initial activity, is superior to malathion against all test species (Lepidoptera, Coleoptera) and is more successful than lindane against many species.

MALLIS, A. 1969. Handbook of Pest Control. 5th Edition. MacNair-Dorland Co., New York. 1158pp.

Furniture infested with powder post and anobiid beetles can be treated by vacuum and vault fumigation with methyl bromide or sulfuryl fluoride.

MARTIN, H. and C. R. WORTHING. 1977. Pesticide manual. British Crop Protection Council, England. 5th Edition. 593pp.

Summarizes the chemical, physical and biological properties of over 500 pesticide active ingredients, presented in alphabetical order of their common names. Relevant data includes references to the corrosiveness of dichlorvos (DDVP) to iron and mild steel, and of chlorpyrifos to copper and brass.

McGAUGHEY, W. H. 1973. Dichlorvos vapor for insect control in a rice mill. J. Econ. Entomol. 66(5): 1147-51.

The effectiveness of dichlorvos in controlling four rice mill pests (Lasioderma serricorne, Tribolium castaneum, Rhyzopertha dominica, and Cadra cautella) is compared to that with a pyrethrins fog. Residue levels on bagged rice following the pesticide application are provided.

McGAUGHEY, C. A. and T. A. PERENICH. 1983. Chromatographic procedures for the analysis of carpet discoloration related to insecticide treatments. University of Georgia research report sponsored by the carpet industry. 47 pp.

The researchers investigated the susceptibility of selected dyed nylon carpets to insecticides under conditions of high humidity, temperature and light. Specific acid and disperse dyes were affected by certain pesticides in high humidity and light conditions. Malathion, Orthene (acephate) and diazinon caused the worst discoloration. Discoloration was caused by chemical interaction.

MONRO, H. A. U. 1972. Manual of fumigation for insect control. UNIPUB, Inc. New York. 381pp.

Leading reference book on fumigation. Relates primarily to conventional fumigants. Principles of fumigation precautions and protective devices, field detection of fumigants, properties of modern fumigants, fumigant mixtures, space fumigation at atmospheric pressure, vacuum fumigation, fumigation of grain bulk, fumigation of standing cups, greenhouse fumigation, bioassay, quarantine treatment, and fumigation schedules are discussed.

MORELAND, D. 1982. The reincarnation of boric acid. Pest Control Technol. 10(11): 32, 44, 51.

Reviews current thinking and research on boric acid and puts it in perspective as a cockroach control product. Key benefits include effectiveness against resistant roach strains, long lasting effects and low repellency to insects. Key disadvantages are slow action and high toxicity to children. Boric acid is particularly useful for treating wall voids, especially during construction to prevent future pest occupancy.

MUTHU, M., et al. 1973. Performance of a dichlorvos-based insecticidal vapour strip in an infested warehouse. Int. Pest Contr. 15(1): 8-10.

Mortality of Tribolium castaneum, Stegobium paniceum, Ephestia cautella, Trogoderma granarium, Sitophilus oryzae, and Bruchus chinensis was high.

PENCE, R. J. and J. MORGANROTH. 1962. Field effects of methyl bromide on carpet beetle eggs. Pest Control 30(7): 20-24.

Methyl bromide fumigation can kill all stages, including eggs. Some stages may survive in pockets where fumigant penetration is inadequate.

PROCTOR, D. L. 1972. The protection of smoke-dried freshwater fish from insect damage during storage in Zambia. J. Stored Prod. Res. 8(2): 139-49.

An emulsion containing 0.018% pyrethrins and 0.036% piperonyl butoxide, applied to smoke-dried freshwater fish in Zambia, prevented infestation by Dermestes ater and D. maculatus (partly by repelling adults) but became ineffective 8-12 weeks after application.

PUNJ, G. K., et al. 1970. Susceptibility to certain fumigants of male and female pupae of Trogoderma granarium Everts (Coleoptera: Dermestidae). J. Stored Prod. Res. 6(3): 263-67.

Male pupae were more susceptible to the fumigants tested than were the female pupae. Of the fumigants tested, methyl bromide was the most toxic, followed by ethylene oxide, carbon disulfide, and ethylene dibromide. Insects from oily foods were less susceptible to carbon disulfide than those from other foods.

QURAISHI, M. S. 1982. A closer look at the safety record of boric acid. Pest Control Technol. 10(11): 34, 35, 47.

This article by a toxicologist from the National Institute of Health, Bethesda, Md., dispels the common misconception that boric acid is an innocuous chemical. Several cases of fatal poisonings, especially of children, are referenced. Warnings are given regarding use of boric acid in research laboratories because of its reactivity and teratogenicity.

RAMBO, G. 1983. Industry faces carpet staining issue. Pest Management 2(2): 21-23.

Summarizes findings of Ad Hoc Pesticide Committee of the Carpet and Rug Institute (CRI) which investigated carpet discoloration by pesticides. 18 red dyes and 12 pesticides were evaluated under conditions of high humidity and high light intensity aimed at accelerating color changes. The results showed that dichlorvos (DDVP), malathion, Sumithion and Orthene caused the worst discoloration. Some pesticide manufacturers have now put warnings on insecticide labels regarding carpet or fabric staining.

REAGAN, B. M. 1983. Effect of selected insecticides on the colorfastness of acid and disperse dyes on nylon and polyester. Dept. of clothing, textiles and interior design, Kansas State University, Manhattan, Kansas. Published in AATCC Book of Papers for 1983 AATCC Natl. Tech. Conf. 16 pp.

This study evaluates the deleterious effects of 20 insecticides on undyed nylon and 47 acid and disperse dyes applied to nylon and polyester carpet yarn, under a range of temperature, humidity and lighting conditions. The insecticides causing the worst discoloration were acephate, carbaryl, dichlorvos, fenitrothion and pyrethrum. Least discoloration was caused by bendiocarb, diazinon and tetramethrin.

REICHMUTH, W., et al. 1963. Investigations on the physical and insecticidal properties of paradichlorobenzene naphthalene and hexachloroethane in control of the clothes moth [Tineola bisselliella (Hum.)]. (GE) Zool. Beitr. 9 (2/3): 197-227.

REIERSON, D. A. and M. K. RUST. 1984. Insecticidal baits and repellency in relation to control of the German cockroach, Blattella germanica (L.). Pest Management 3(6): 26-32.

Results of tests on baits containing boric acid, chlorpyrifos, acephate, propoxur and amidinohydrazone are reported. Baits containing 2% amidinohydrazone (MaxForce, Combat) gave best results under lab and field conditions. Good results with baits are correlated with low repellency and slow action of the toxicant. Fenvalerate was reported as highly repellent and performed poorly compared with other insecticides in choice box tests.

RICHARDSON, H. 1975. Freight container fumigation and wood penetration by ethylene oxide mixture against quarantinable termites and other insects. Pest Control 43(9): 20, 22-24.

The reports indicate that ethylene oxide-carbon dioxide 10:90 mixture had high efficiency against 3 species of flour beetles and against 2 species of termites.

RYCKMAN, R. E. 1969. Vapona for the control of museum pests. J. Med. Entomol. 6(1): 98.

Vapona cheaper, lasts longer, not as toxic to man as other fumigants.

SANDHU, G. S. 1975. Studies on insects infesting wooden and bamboo household articles and their control. J. Res. Punjab Agric. Univ. 12(2): 152-55.

Spraying with 0.1% lindane gave complete control of Lyctus africanus and Dinoderus ocellaris in wooden household articles.

SHAW, T. and M. A. WHITE. 1983. The chemical technology of wool finishing. Chapt. 5 in Handbook of fiber science and technology: Vol. II, Part B (Edt. M. Lewin and S. B. Sello). Marcel Dekker, New York. pp. 382-395.

Good summary of insectproofing chemicals and their uses, including the new persistent pyrethroids. The potential of fiber-reactive derivatives of organophosphorus insecticides as mothproofers is mentioned.

SLATTER, R., et al. 1981. An evaluation of pestigas BB- a new system for applying synthetic pyrethroids as space sprays using pressurized carbon dioxide. Int. Pest Control 23(6): 162-64.

Equipment using carbon dioxide as both co-solvent and propellent for insecticide mixtures provided excellent control of flying insects and variable but useful control of crawling insects. The advantages of this dispersal technique are discussed.

STAMATINIS, N. C. 1935. The enemies of tobacco in warehouses. Ephestia elutella Hb. and Lasioderma serricorne (Fab.). The biology and measures for their control. Rev. Appl. Entomol. (A)23: 259, 1935.

90:10 mixture of ethylene oxide and carbon dioxide at 4 ounces per 100 cu.ft. for 48 hours gave good control of cigarette beetle.

STORY, K. O. 1972. Control of cockroaches and other domestic pests with a new carbamate insecticide. Int. Pest. Contr. 14(6): 6-10.

The odorless, non-irritant carbamate insecticide bendiocarb is effective against 6 cockroach species, ants, carpet beetles, mosquitoes, bedbugs and fleas.

STORY, K. O. 1984. Product profile - Mop Up insecticide. Pest Control Technol. 12(7): 61-63.

Field trials with Mop Up, a soluble form of boric acid applied in mop water by cleaning staff, showed that it was a useful adjunct to other German cockroach control measures. At all test sites the population of cockroaches was reduced by the mop water additive and there were no problems associated with its use.

STORY, K. O. 1985. Technology review - the new and the newer. Pest Control 53(5): 28-30, 32.

Review of new application and monitoring equipment, and new chemicals for pest management. Includes summary of benefits of hydroprene insect growth regulator and the pyrethroids fenvalerate and cypermethrin.

STORY, K. O. 1985. Pest management in aircraft. Pest Control Technol. 13(10): 4pp.

Describes approaches to dealing with pests on board aircraft. Particularly emphasizes risks of using pesticides which have not been specifically tested regarding corrosiveness to aircraft materials. Cites successful use of bendiocarb which has passed aircraft corrosion tests and is safe on acrylics, carpeting, metals and other aircraft materials. Warns against use of dichlorvos or chlorpyrifos because of metal corrosion.

STRONG, R. G. 1970. Relative susceptibility of Attagenus alfierii and A. megatoma larvae to several organophosphorus insecticides. J. Econ. Entomol. 63(1): 286-87.

Fenitrothion, dicapthon, fenthion most effective.

TAYLOR, J. M. 1961. The use of contact insecticides for the control of certain wood-boring insects. Rec. Annu. Conv. Brit. Wood Preserv. Ass., London: 13p. and 1961 Pest Technol., London 3(12): 276-81.

Emulsified solutions of DDT, lindane or dieldrin were suitable surface treatments for short-term protection against lyctids, anobiids and cerambycids but oil solutions better for long-term protection.

TAYLOR, J. M. 1967. Toxicity of boron compounds to the common furniture and longhorn beetles. Int. Pest Control 9(1): 14-17.

Prevents survival of larvae of Anobium and Hylotrupes.

TENHET, J. N. 1955. Timing of sprays to control the cigarette beetle. USDA ARS, Wash., D.C. AMS-49: 6p.

It is recommended on the basis of these investigations that periodic applications of pyrethrum sprays or aerosols for the control of stored tobacco insects in tobacco warehouses be made between 6 p.m. and midnight to coincide with the greatest activity of the cigarette beetle. These beetles were trapped by tanglefoot paper as they emerged from hogsheads in cages in tobacco warehouses in summer 1954, Durham, N.C.

TENHET, J. N., et al. 1957. Studies of DDVP for control of cigarette beetles in tobacco warehouses. USDA Agric. Mark. Serv. AMS-214: 16p.

Insects in free spaces killed in 1 hour. At 1 gm/1,000 cu ft; solutions sprinkled in aisles required 20 hours.

TENHET, J. N., et al. 1958. Further studies on the control of the cigarette beetle with DDVP. Tobacco Sci. 147(6): 106-10.

One gram DDVP per 1,000 cu ft. of warehouse killed all caged beetles.

TITTANEN, K. 1971. The efficiency of a pyrethrins aerosol against the larvae of the clothes moth (Tineola bisselliella). Pyrethrum Post 11(1): 15-17.

The efficiency and residual life of aerosols containing pyrethrins and aerosols containing DDT and lindane were about equal when applied to woolen fabrics for protection against T. bisselliella.

TOSKINA, I. N. 1969. Protecting wood from destruction by the common furniture beetle (Anobium punctatum). Sb. Rab. Mosk. Lesotehk. Inst. 26: 215-25.

to protect beams from Anobium punctatum, an evaluation was made of various substances used to soak or cover the wood. Included among these were lacquer, copal lacquer, drying oil (a boiled linseed or hempseed oil), oil paints, red lead, urea-formaldehyde resin and bis-phenol-a.

UEHARA, K., K. NAGATA and T. MATSUMURA. 1982. Studies on the control of Cephalonomia gallicola. I. Susceptibility of the drugstore beetle, Stegobium paniceum to several insecticides. Jap. J. Sanit. Zool. 33(3): 249-50.

Lethal and knockdown effects of several insecticides on the drugstore beetle were examined in the laboratory. Fenitrothion showed the most effectiveness using the topical application method. In the contact test, dichlorvos was the most effective in quick knockdown.

WILLIAMS, L. H. 1973. Recognition and control of wood destroying beetles. Pest Contr. 41(2): 24, 26, 28.

Habits and control recommendations are given for lyctids, anobiids, scolytids, and old house borers.

WILLIAMS, L. H. and H. R. JOHNSTON. 1972. Controlling wood-destroying beetles in buildings and furniture. USDA leaflet No. 558: 1-8.

WRIGHT, C. G. 1982. Effective control of German cockroaches with several promising insecticide formulations. Pest Management 1(7): 24-26.

Aerosol formulations of permethrin, Safrotin, Actellic, encapsulated diazinon and boric acid, and spray formulations of Dursban and Orthene all achieved good control when injected into cracks and crevices in infested homes.

WRIGHT, C. G. and H. E. DUPREE. 1984. Insect control around houses.

Research at North Carolina State University found that occasionally invading arthropods can be controlled by applying residual insecticides around the exterior perimeter of buildings. Sprays of 0.25% Ficam (bendiocarb) gave generally better results against cockroaches, beetles, ants, spiders, etc. than sprays of Orthene (acephate), or baits containing Orthene or Baygon. In most cases control lasted a few weeks only.

ZETTLER, J. L., et al. 1974. Sublethal doses of malathion and dichlorvos: effects on fecundity of the black carpet beetle. J. Econ. Entomol. 67(1): 19-21.

Fecundity was reduced 63% by malathion and 74% by dichlorvos.

ZUNGOLI, P. and W. H. ROBINSON. 1982. Crack and crevice outshines fan-spray treatment. Pest Control 50(6): 20, 22.

VPI researchers show that crack and crevice applications of Orthene and Ficam are more effective against German cockroaches than fan-spray techniques.

USE OF ATMOSPHERIC GASES

Because conventional fumigants are highly toxic to people, sometimes highly reactive with materials, and highly regulated, the use of atmospheric gases as fumigants deserves consideration. These gases are carbon dioxide, and so-called inert gases such as nitrogen and helium. The advantage of these gases over conventional fumigants is that user risks appear to be limited to short-term acute toxicity effects and not long-term effects arising from chronic exposure. Thus, where threshold limit values for conventional fumigants might be 5 ppm, the TLV set for carbon dioxide by the American Conference of Governmental Industrial Hygienists is 5,000 ppm based on a 5 day, 35 to 40 hour work week. Any escape of carbon dioxide from leaks in the equipment or from the area being fumigated would, in most cases, soon blend into the atmosphere and fall within safe limits. However, carbon dioxide must not be handled in a cavalier fashion. This is because it regulates the breathing function in vertebrates, and an increase in carbon dioxide inhaled causes an increased rate of breathing. A two percent concentration in air causes a 50% increase in respiration, and a 5% concentration causes a 300% increase in respiration. At concentrations lethal to insects, self-contained breathing apparatus is essential before entering an area undergoing carbon dioxide fumigation.

From a practical viewpoint the focus in use of atmospheric gases should be on carbon dioxide rather than the inert gases. This is because carbon dioxide is effective at levels as low as 30%, when there is still 70% air (i.e. 15% oxygen) present. In contrast, inert gases require the oxygen level to be reduced to below 2% and maintained at this level many times longer than with carbon dioxide. It is very hard holding such a low level of oxygen, and even in carbon dioxide fumigation of buildings it has been difficult to hold the concentration at a lethal level.

The notes accompanying the references in the bibliography further describe the uses and limitations of atmospheric gases. In summary, a concentration of 60% carbon dioxide held for four days at a temperature of 70°F or higher will kill all life stages of most pests.

Regarding effects on materials, atmospheric gases are less reactive than some conventional fumigants and there is no problem of residues for people who subsequently handle treated items. However, carbon dioxide will react with water to form carbonic acid which may harm some materials.

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BIBLIOGRAPHY

SECTION 8 - Use of Atmospheric Gases

ALI NIAZEE, M. T. 1971. The effect of carbon dioxide gas alone or in combinations on the mortality of Tribolium castaneum (Herbst) and T. confusum (Du Val) (Coleoptera: Tenebrionidae). J. Stored Prod. Res. 7(4): 243-52.

Adults exposed to various mixtures of nitrogen or helium and oxygen were killed when the oxygen concentration reached to 1.7% or below, whereas the adults exposed to carbon dioxide + oxygen mixtures were killed mostly due to the deleterious effects of carbon dioxide itself.

ALI NIAZEE, M. T. 1972. Susceptibility of the confused and red flour beetles to anoxia produced by helium and nitrogen at various temperatures. J. Econ. Entomol. 65(1): 60-64.

The adult stage was most susceptible to 100% N2 and HE atmospheres followed by the larval, egg and pupal stages. Helium was more toxic than nitrogen, especially to the adults at lower relative humidity.

ANONYMOUS - USDA ARS. 1966. Stored grain pests doomed by polluted air, USDA says. Pest Control 34(7): 52, 54.

By adding carbon dioxide to the air, an atmosphere is created in which insects cannot live.

BANKS, H. J. 1978. Recent advances in the use of modified atmospheres for stored product pest control. Proc. 2nd International Working Conference on Stored Product Entomology. Ibadan, Nigeria.

Good review of the field, particularly trials in Australia which showed that pesticidal atmospheres based on nitrogen or carbon dioxide can be achieved in a wide variety of storages and other enclosures, including freight containers. 37 references.

BANKS, H. J. and P. C. ANNIS. 1977. Suggested procedures for controlled atmosphere storage of dry grain. CSIRO, Australia. Div. of Entomol. Tech. Paper No. 13: 23pp.

Practical guide to grain storage under controlled atmospheres for insect control. Includes structural requirements, exposure periods, instrumentation and safety factors. Primarily relates to nitrogen atmospheres.

BOND, E. J. and C. T. BUCKLAND. 1979. Development of resistance of carbon dioxide in the granary weevil. J. Econ. Entomol. 72(5): 770-71.

Treatment of successive generations of Sitophilus granarius adults with carbon dioxide produced insects with a 3-fold increase in tolerance to the gas in 7 generations.

CANTWELL, G. E., et al. 1973. Control of the German cockroach with carbon dioxide. Pest Contr. 41(3): 40, 42, 48.

Exposure of German cockroaches to concentrations of carbon dioxide above 90% resulted in 100% mortality to nymphs and adults when held at 90°F for 3 hours. However, it took 4½ hours to obtain 100% mortality and no hatch from ootheca bearing females.

DAVIS, R. and E. G. JAY. 1977. The current status of controlled atmospheres as a method of insect control. Proc. 2nd Natl. Controlled Atmos. Res. Conf., Mich. State Univ., Hortic. Rep. No. 28: 207-11.

Insect pests in harvested agricultural commodities can be controlled by controlled atmospheres. Carbon monoxide, carbon dioxide, and nitrogen have been used to lower the oxygen content within a storage facility. Methods of altering the atmospheric gas mixture externally include vaporization of liquefied nitrogen or carbon dioxide, the removal of the oxygen by burning hydrocarbons, aerobic fermentation of carbohydrates, electrolytic oxygen pumping systems, or on-site air liquification, distillation and reintroduction. Choice of mixture is dependent on a number of variables.

DAVIS, R. and E. G. JAY. 1983. An overview of modified atmospheres for insect control. Assoc. Operative Millers Bull. March, 1983: 4026-29.

Modified atmospheres such as carbon dioxide offer a residue-free method of controlling stored product insects in stored food. It also shows potential for use in-transit, but not all vehicle types have been studied.

JAY, E. G. 1971. Suggested conditions and procedures for using carbon dioxide to control insects in grain storage facilities. USDA Ag. Res. Serv. 51-46, Sept. 1971: 6pp.

Above 70°F, a carbon dioxide concentration of 60% for 4 days will kill most species and life stages of stored product insects. Eggs and adults of several species of moths and beetles are killed in shorter exposure periods. Alternatively 45% carbon dioxide can be used for 5 to 6 days or 35% for 7 days.

JAY, E. G. 1980. Methods of applying carbon dioxide for insect control in stored grain. USDA/SEA. Adv. in Agri. Technol., Southern Series, No. 13: 7pp.

Three methods of applying carbon dioxide to silos are described. Comparative purge times, carbon dioxide requirements and costs are given. Good introductory section on use of carbon dioxide and its value where leakiness of gas is a problem.

JAY, E. G., G. E. CANTWELL, G. C. PEARMAN, Jr. and J. V. THOMPSON. Undated. Control of the greater wax moth, *Galleria mellonella* (Linnaeus), in comb honey with carbon dioxide. Pt. II. Field studies.

Semitrailer van loads of comb honey were treated with an average of 98.6% carbon dioxide for 10 to 12 hours. Average mortality of caged wax moths was 97.8%.

JAY, E. G. and W. CUFF. 1981. Weight loss and mortality of three life stages of Tribolium castaneum (Herbst) when exposed to four modified atmospheres. J. Stored Prod. Res. 17: 117-124.

99% nitrogen caused greater mortality in adults than 58% carbon dioxide, while 58% carbon dioxide was more effective against pupae.

JAY, E. G., et al. 1969. Protecting wheat stored in metal cans with carbon dioxide. J. Ga. Entomol. Soc. 4(4): 181-86.

Effective only in tightly sealed cans; cost per liter of wheat was 0.05¢.

JAY, E. G., et al. 1971. Relative humidity: its importance in the control of stored-product insects with modified atmospheric gas concentrations. J. Stored Prod. Res. 6(4): 325-29.

Adults of Tribolium confusum and T. castaneum, and Oryzaephilus surinamensis were exposed at 4 relative humidities to binary mixtures of oxygen and nitrogen or to ternary mixtures of oxygen, nitrogen and carbon dioxide. In most instances, mortality increased with decreased relative humidity when the insects were exposed for limited periods of time to either the binary or the ternary mixtures.

JAY, E. G., et al. 1971. Susceptibility of two species of Tribolium (Coleoptera: Tenebrionidae) to alterations of atmospheric gas concentrations. J. Stored Prod. Res. 7(3): 181-86.

In most instances an increase in carbon dioxide or nitrogen combined with a decrease in oxygen resulted in increased mortality.

JAY, E. G., et al. 1973. Carbon dioxide for control of an insect infestation in stored corn (maize). J. Stored Prod. Res. 9(1): 25-29.

The method evaluated appears to offer promise; however, techniques need to be improved to reduce costs.

LINDGREN, D. L., et al. 1970. Effect of atmospheric gases alone or in combination on the mortality of granary and rice weevils. J. Econ. Entomol. 63(6): 1926-29.

Atmospheres of carbon dioxide, nitrogen, helium, carbon dioxide + air, and carbon dioxide + oxygen were evaluated.

MARZKE, F. O., et al. 1970. Mortality of the rice weevil, the Indian meal moth, and Trogoderma glabrum exposed to mixtures of atmospheric gases at various temperatures. J. Econ. Entomol. 63(2): 570-74.

Atmospheres highly lethal to moth pupae. However, for the atmospheres to be highly lethal to T. glabrum larvae, the oxygen had to be reduced to 7% and carbon dioxide increased to 60%.

RONAI, K. S. and E. G. JAY. 1982. Experimental studies on using carbon dioxide to replace conventional fumigants in bulk flour shipments. Assoc. Operative Millers Bull. August 1982: 3954-58.

Refers to earlier work which indicated that a 4 day treatment of about 60% carbon dioxide will give good control of all life stages (including eggs) of

most stored product insects at 80°F or higher. These studies showed that the use of carbon dioxide in the form of dry ice to control confused flour beetles in flour in hopper cars was feasible. Dry ice costs were higher than with conventional fumigants but absence of residues and lower need for aeration were big advantages of carbon dioxide.

SHARP, A. K. 1979. Disinfestation of grain with carbon dioxide in freight containers. Proc. 1979 Ann. Conf. Aust. Inst. Ag. Sci.: 78-84.

Freight containers are satisfactory for carbon dioxide fumigation and dry ice is a convenient source of gas. Continuing addition of gas is needed to compensate for leakage. Dry ice enclosed in an insulated box in the freight container is a simply way to make up the gas level.

SHERJBAL, J. (Editor). 1980. Controlled atmosphere storage of grains. Proc. of International Symposium, Castelgandolfo, Italy. 1980. Elsevier Scientific Publishing Co., New York.

Papers on subjects ranging from naturally occurring oxygen-poor atmospheres in underground pits to automatic inert gas industrial stores.

SODERSTROM, E. L. and D. G. BRANDL. 1982. Antifeeding effect of modified atmospheres on larvae of the navel orangeworm and Indian meal moth (Lepidoptera: Pyralidae). J. Econ. Entomol. 75(4): 704-05.

The modification of the atmosphere inside large almost storage bins in California was evaluated for its effect on feeding or anti-feeding of larvae of the navel orangeworm, and Indian meal moth. Nitrogen-enriched atmospheres containing 1% oxygen were effective in preventing feeding, but those containing higher levels of oxygen were not. Carbon dioxide at 40% concentration was effective against both species, but carbon dioxide at 30% concentration was effective only against the navel orangeworm.

STOREY, C. L. 1973. Exothermic inert-atmosphere generators for control of insects in stored wheat. J. Econ. Entomol. 66(2): 511-14.

Atmospheric concentrations containing less than 1% oxygen for 24 hours killed adult confused flour beetles, Tribolium confusum, but were not effective against immature stages of Sitophilus oryzae for time periods of 72-96 hours.

STOREY, C. L. 1975. Mortality of Sitophilus oryzae (L.) and S. granarius (L.) in atmospheres produced by an exothermic inert atmosphere generator. J. Stored Prod. Res. 11(3/4): 217-21.

Young larval and adult beetles were more susceptible to inert atmospheres than pupae.

STOREY, C. L. 1975. Mortality of three stored product moths in atmospheres produced by an exothermic inert atmosphere generator. J. Econ. Entomol. 68(6): 736-38.

All stages of the Indian meal moth and almond moth were killed by 24 hour exposures to atmospheres of less than 1% oxygen; 120 hours was required to cause 100% mortality in larvae and pupae of the angoumois grain moth.

YOUNG, S. Y., et al. 1970. Effect of carbon dioxide anesthesia on malathion toxicity to four species of stored-product insects. Ann. Entomol. Soc. Amer. 63(2): 381-82.

Mortality from malathion increased when adults of red flour beetle or cigarette beetle or larvae of black carpet beetle anesthetized for as little as 5 minutes; mortality of adults of confused flour beetles after 60 minutes of anesthesia.

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PART II: SECTION 9

USE OF NON-CONVENTIONAL OR LOW TOXICITY PESTICIDES

There are many non-conventional chemicals which have been little explored, which are not labeled and which have been little, if ever, used for control of museum pests. In addition, there are various "low toxicity" pesticides, some of which are labeled but little used for museum pests, but most of which are labeled for agricultural or other purposes and not for museum pests. These various materials include the following:

(a) Feeding inhibitors, e.g. thioureas.

(b) Growth retardants, e.g. sterols.

(c) Antimetabolites, e.g. imidazole.

(d) Chitin inhibitors.

(e) Oviposition inhibitors.

(f) Vitamins, e.g. Vitamin K (excesses can be used to kill insects).

(g) Chemosterilants.

(h) Inhibitors of micro-organism symbionts of insects, e.g. sorbic acid.

(i) Repellants, e.g. R11

(j) Attractant salts.

(k) Inert dusts, e.g. silica aerogel, diatomaceous earth.

(l) Juvenile hormones, e.g. methoprene, hydroprene.

(m) Anti-juvenile hormones, e.g. compactin, fluoromevalonate.

(n) Pyrethroids, e.g. resmethrin, permethrin, cypermethrin, fenvalerate, d-phenothrin,tetramethrin, d-trans allethrin.

(o) Low toxicity organophosphates, e.g. pirimiphos methyl.

Those chemicals in sections (a) to (h) are little explored from an efficacy viewpoint, are not registered as pesticides and may not be economic or safe. Nonetheless, it is postulated that because some of them (e.g. chitin inhibitors) work on systems found only in arthropods, they are unlikely to have harmful effects on people.

Repellents and attractants seem worthy of more research, particularly because they would not be subject to the rigorous registration process which true pesticides have to undergo (this EPA registration process typically takes 5 years and costs $5 million to $15 million for a new active ingredient). Attractants could be used to draw pests away from sensitive areas towards a trapping zone. Repellents could be used on or immediately around vulnerable items to discourage insect attack. The effectiveness of some standard insecticides, including lindane and pyrethrum, is due in part to their repellancy, so this approach has proven merit.

The so-called inert dusts such as silica aerogel are best referred to as dessicant dusts because they work by abrading or absorbing the waxy protective coating of insects and causing them to die from water loss. They are widely used for control of cockroaches and drywood termites but little used against most museum pests. Some museum pests, particularly the hairy larvae of carpet and hide beetles, are hard to kill with such dessicant dusts. This is perhaps because the hairs prevent their bodies making intimate contact with the dust. Nonetheless, because they are long lasting and have low toxicity they should be used more against vulnerable pests, particularly since insects cannot develop a physiological resistance to them. In connection with dessicant dusts it should be pointed out that some are nasal irritants and can cause discomfort to those applying them or handling treated items.

Juvenile hormones show great promise for control of some museum pests. For instance, methoprene has provided very long control of cigarette beetles in tests. However, currently methoprene is only registered for use against fleas, ants and mosquitoes. Hydroprene is a juvenile hormone which became commercially available in 1985 for control of cockroaches. In most cases, these juvenile hormones are very slow acting and need to be used in conjunction with conventional insecticides to achieve faster results. Their key advantage is their low toxicity to humans.

There are no anti-juvenile hormones yet available for any pests, but some experimental ones show great promise against lepidoptera. The advantage of these compared with juvenile hormones is that, whereas juvenile hormones prolong the larval stage and result in unviable or infertile adults, the anti-juvenile hormones shorten the larval stage (which results in dwarf, unviable adults). Clearly shortening the larval stage is desirable when it is the larval stage which is destructive (e.g. clothes moths and carpet beetles). It is expected to be at least another decade before any anti-juvenile hormones become commercially available at the current rate of research.

Pyrethroids show great promise for control of museum pests and some, particularly resmethrin, are already available for museum pests. Others, such as permethrin, are only available for agricultural use but their labels are being extended to include pests of buildings. In 1985, fenvalerate and cypermethrin became available for pest control in buildings, particularly for cockroach control. Previously they had only been used against crop pests in the United States though, in common with permethrin and others, they had been used for many years overseas against pests of buildings. The new generation pyrethroids such as permethrin, cypermethrin and fenvalerate bear little relationship to natural pyrethrum. In particular, they are much more persistant, providing many months of insect control when applied to favorable surfaces such as woolen cloth or wood. Indeed, because of its persistence, permethrin was commercially introduced in 1980 by Shell and Wellcome as the active ingredient in new mothproofing agents. More recently, Bayer and Ciba-Geigy have also introduced mothproofing agents based on new synthetic pyrethroids.

These pyrethroid-based mothproofing agents are expected to substantially increase in use because of their efficacy against a broad spectrum of larvae which eat wool, and because of their image (not yet deserved) of being safer than traditional mothproofing agents. Unfortunately, they tend to be more toxic to non-target species than natural pyrethrum (e.g. they are among the most poisonous substances known against fish). Also, in common with natural pyrethrum, the pyrethroids can be irritant and allergenic, especially the alpha-cyano pyrethroids, such as cypermethrin and fenvalerate. Further, some of the new pyrethroids are suspect oncogens, a factor which has delayed their commercial introduction as insecticide sprays against pests in buildings. Nonetheless, because of their low acute (i.e. short-term) toxicity to mammals they are expected to become widely used as insecticide sprays, and their labeling is expected to include many pests found in museums. However, many insects seem to be quickly able to develop resistance to the new pyrethroids and as a result their useful market life is likely to be shorter than many other mothproofing agents.

The organophosphate pirimiphos methyl has been widely used as a grain additive for control of grain beetles and it shows promise for control of museum pests. Its key advantage is its relatively low toxicity (acute oral LD50 to rats is 2,000 mg/kg). It should be relatively easy to extend its labeling to include museum pests, but it may not be safe to use on some surfaces (e.g. it is slightly corrosive to tin and mild steel).

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BIBLIOGRAPHY

SECTION 9 - Use of Non-conventional or Low Toxicity Pesticides including new pyrethroids, antifeedants and repellants.

ANONYMOUS. 1978. Control of death-watch beetle in HMS Victory. Int. Pest Control 20(6): 2.

During renovation of the historic HMS Victory in England, it was found that annual treatments would be necessary for control of death-watch beetles. The treatment of choice will be insecticidal smoke in the holds and an emulsion of permethrin in all other areas.

ANONYMOUS. 1983. Attacking hospital roaches. Pest Control 51(9): 30, 32, 33.

Laudatory article about use of MaxForce cockroach bait in hospitals. The ease of use and apparent safety of this amidinohydrazone insecticide which is marketed in tamperproof roach feeding stations is highlighted.

ANONYMOUS. 1984. Cockroaches now await Zoecon Corporation's birth control product. Pest Control 52(11): 54, 55.

Launch article for Zoecon's new insect growth regulator Gencor for cockroach control. Based on hydroprene, this product prevents roach reproduction but does not kill existing nymphs and adults. Roach populations slowly die out after exposure to Gencor. In one test 95% control was achieved after 8 months. Hydroprene appears to be significantly safer to non-target species than more conventional insecticides.

ASCHER, K. R. S. 1970. Insect pest control by chemosterilants and antifeedants - Magdeburg 1966 to Milan 1969. World Rev. Pest Contr. 9(4): 140-55.

Research on chemosterilants used in controlling houseflies, Mexican fruit flies, onion maggots, mosquitoes, cabbage loopers, boll weevils, pink bollworms, codling moths, Japanese beetles, and bark beetles is discussed. Worldwide research on organometallic antifeedants, American Cyanamid antifeeding compound 24,055 and the botanical antifeedant, Neem, is also reviewed.

BERCK, B. 1966. Some relationships between atmospheric gases and biocidal effectiveness of fumigants applied to wheat in hermetic storage. Proc. N. Dakota Acad. Sci. 20: 100-101.

BHATNAGAR-THOMAS, P. L. 1973. Control of insect pests of stored grains using a juvenile hormone analogue. J. Econ. Entomol. 66(1): 277-78.

Test insects included Tribolium castaneum, Stegobium paniceum, Bruchus chinensis, Sitophilus granarius, and Rhyzopertha dominica.

BHATNAGAR-THOMAS, P. L. 1976. Synergistic pesticidal action of juvenile hormone analogue and beta-ecdysone on diapausing larvae of khapra beetle Trogoderma granarium Everts. J. Food Sci. Technol., Mysore 13 (Sep-Oct): 259-61.

Diapause in 90% of khapra beetle larvae is terminated in about 11 days with high concentrations of beta-ecdysone.

BOUSH, G. M., et al. 1968. Progeny suppression of Attagenus megatoma and Trogoderma parabile by dietary factors. J. Econ. Entomol. 61(3): 644-46.

Sorbic acid adversely affected survival of progeny beyond first instar.

BRY, R. E., R. E. BOATRIGHT and J. H. LANG. 1982. Permethrin: effectiveness of low deposits against three species of fabric insects. J. Ga. Entomol. Soc. 17(1): 46-53.

Woolen cloth treated with permethrin at a deposit as low as 0.002% by weight of the cloth was satisfactorily protected against feeding by larvae of the black carpet beetle, Attagenus megatoma and the webbing clothes moth, Tineola bisselliella, both after the treatments had aged for 3 and 6 months.

BRY, R. E., et al. 1968. Allethrin as a protectant of woolen fabric against black carpet beetle larval damage. J. Econ. Entomol. 61(5): 1194-97.

Applied in emulsion baths at temperatures of 54.4 and 100°C.

BRY, R. E., et al. 1969. 1969 status report of stored-product insects research of military importance: 1. Investigation of candidate mothproofers. 2. Development of mothproofing formulations and application techniques. 3. Application studies with quarternary ammonium compounds (3 articles). USDA Stored Prod. Insects Res. Dev. Lab., Savannah, Ga., AFPCB Meet., Savannah, Mar. 10-14: 18, 19, 20-21.

1. Four of 31 compounds tested as mothproofers protected woolen cloth from black carpet beetle larval feeding. 2. Gardona, bay 75546 and bay 79845 protected against black carpet beetle. 3. Most effective compounds against webbing clothes moth were aliquat 336, 202 and 203, applied as padding and sorption treatments.

BRY, R. E., et al. 1969. Gardona as a mothproofer of woolen fabric. J. Econ. Entomol. 62(4): 868-72.

Deposits as low as 0.001% by weight protected against damage by Attagenus megatoma and Tineola bisselliella.

BRY, R. E., et al. 1970. Mothproofing investigations with imidazole. J. Econ. Entomol. 63(1): 71-74.

Boric acid was more effective than this antimetabolite.

BRY, R. E., et al. 1971. Gardona applied to woolen fabric as a mothproofer during drycleaning. J. Econ. Entomol. 64(2): 530-33.

Gardona protected woolen cloth against Attagenus megatoma at deposits as low as 0.08% by weight. Gardona can effectively be applied during the dry-cleaning process.

BRY, R. E., et al. 1971. Gardona as a protectant of rubberized hair cushioning material against black carpet beetle damage. J. Econ. Entomol. 64(3): 754-55.

Gardona emulsion spray shows promise as a replacement for DDT.

BRY, R. E., et al. 1972. Surfactants as protectants of woolen fabric against black carpet beetle larval damage. J. Ga. Entomol. Soc. 7(3): 196-204.

Evaluations of 76 surfactants comprising anionic, cationic, and nonionic types were made. Cationic surfactants were the most satisfactory.

BRY, R. E., et al. 1973. Protection of woolen carpeting against black carpet beetle larval damage: investigation of six compounds. J. Econ. Entomol. 66(2): 546-48.

Treatment with aliquat 336, perthane, and strobane tended to cause early carpet soiling. Methoxychlor did not provide protection after shampooing. Iodofenphos and gardona were the most promising of the 6 compounds.

BRY, R. E., et al. 1973. Protecting woolen fabric against insect damage with resmethrin. Soap Cosmet. Chem. Spec., N.Y.: March, 3p.

Protected against black carpet beetle and webbing clothes moth larvae.

BRY, R. E., et al. 1973. Toxicity of resmethrin to carpet beetles and clothes moths. Pest Contr. 41(11): 32, 47.

Resmethrin as an oil spray or aqueous spray was effective when applied as a direct contact spray against both larvae and adults.

BRY, R. E., et al. 1973. Candidate repellents for mothproofing: preliminary investigations with black carpet beetle larvae (Coleoptera: Dermestidae). J. Ga. Entomol. Soc. 8(4): 306-09.

Of 19 compounds tested, four gave satisfactory protection.

BRY, R. E., et al. 1976. Durability of FMC 33297 in mothproofing. Soap Cosmet. Chem. Spec., Jul: 4p.

FMC 33297, a synthetic pyrethroid, was not toxic to black carpet beetles, but was always highly toxic to webbing clothes moth larvae.

BRY, R. E., et al. 1978. Mothproofing: candidate repellents against black carpet beetle larvae (Coleoptera: Dermestidae). J. Ga. Entomol. Soc. 13(1): 63-66.

Sixteen candidate repellents were applied to woolen cloth at 0.5 and 3.0% by weight and tested against larvae of Attagenus megatoma. Six of the compounds satisfactorily protected the cloth against larval damage at the 3.0% deposit level.

BRY, R. E., et al. 1979. Permethrin sprays effective against fabric pests. Soap Cosmet. Chem. Spec. 55(12): 42-45.

Tests were done to determine the effectiveness of 2 formulations of permethrin against *Attagenus megatoma*, *Anthrenus flavipes*, and *Tineola bisselliella*. Both formulations protected the cloth from larval damage but mortality to insects was greater when exposed to the oil-based formulation.

BRY, R. E., et al. 1981. "Sumithrin" spray effective against fabric pests. Soap Cosmet. Chem. Spec. May: 3p.

This paper reports on (1) the effectiveness of d-phenothrin sprayed on woolen cloth to protect it against damage by carpet beetle and clothes moth larvae both initially and after aging, (2) the amount of insecticide on the cloth both initially and after aging, and (3) the effectiveness of d-phenothrin spray applied directly to both larvae and adults of both pests.

BRY, R. E. and J. H. LANG. 1967. O,o-diethyl phosphorothioate o-ester with phenylglyoxylonitrile oxime (bay 77488) as a mothproofer of woolen fabrics. Textile Res. J. 37(11): 915-19.

At deposits as low as 0.5% by weight, bay 77488 satisfactorily protected woolen cloth against feeding damage by larvae of the black carpet beetle *Attagenus piceus* and of the webbing clothes moth *Tineola bisselliella*. The biological data also showed the bay 77488 residues to be moderately resistant to washing, highly resistant to drycleaning, and persistent through aging for at least 12 months. The oral LD50 to rats is more than 1,000 mg/kg.

BRY, R. E., J. H. LANG and R. E. BOATRIGHT. 1983. Toxicity of three pyrethroid insecticides to eggs of the black carpet beetle and the webbing clothes moth. J. Ga. Entomol. Soc. 18(3): 394-98.

Fenvalerate, d-phenothrin and tetramethrin were tested on wool fabric for their effect on eggs of the black carpet beetle, and webbing clothes moth. Tetramethrin was the most effective, with fenvalerate and d-phenothrin only moderately toxic to the black carpet beetle eggs. Fenvalerate yielded better control of webbing clothes moth eggs.

BURDEN, G. S. and B. J. SMITTLE. 1963. Chemosterilant studies with the German cockroach. Florida Entomol. 46: 229-234.

Tests on chemosterilants as a means of controlling roaches.

COLEMAN, G. R. 1977. Toxicity of permethrin smoke to adult death watch beetle *Xestobium rufovillosum*. Int. Biodeterior. Bull. 13(2): 49-50.

Permethrin is 2 to 3 times more toxic and significantly more permanent than lindane.

DA SILVA, E. and M. E. SOUSA. 1967. A study of inert dusts used against stored product pests. Garcia de Orta, Lisbon 15(3): 367-407.

These inert dusts have no toxicity to man, but by disrupting the waterproof wax layer of the insect cuticle, either by abrasive or absorptive action, they induce an abnormal water loss fatal to the insect. The efficacy of such products is affected by the age, sex and stage of the insects to be controlled, temperature, humidity and dust formulation (concentration, moisture content, hardness).

DE LONG, D. 1962. Beer cases and soft drink cartons as insect distributors. Pest Control 30(7): 14, 16, 18.

The use of repellents such as R11 to exclude cockroaches from cartons.

DODD, G. D. 1983. Space spraying in practice - a review. Proc. 6th Brit. Pest Control Conf. Cambridge. Published by Brit. Pest Control Assoc. London. Paper No. 10: 15pp.

Review of the uses of space sprays against both flying and crawling pests. Main value of non-residual space sprays is in killing flying pests, or flushing crawling pests from harborages and thus contributing to crawling pest control where use of residual insecticides is restricted. Space sprays of pyrethrins and of the residual pyrethroid permethrin have both achieved control of tobacco beetles.

EBELING, W. 1971. Sorptive dusts for pest control. Annu. Rev. Entomol. 16: 123-58.

A discussion of the mode of action of sorptive dusts and their practical application in controlling drywood termites, household roaches, ectoparasites, stored products pests and plant pests is presented.

EBELING, W. 1973. Dust desiccants: effect of prolonged exposure of films on insecticidal efficacy. J. Econ. Entomol. 66(1): 280-82.

Some physical and/or chemical change takes place when dust desiccants are exposed for extended periods to moist atmosphere in a thin film.

EBELING, W. and R. E. WAGNER. 1964. "Built in" pest control for wall and cabinet voids in houses and other buildings under construction. Calif. Agr. 18(11): 8.

Long lasting control of several species of cockroaches was obtained by applying three grams of silica aerogel per interstud void.

EDWARDS, J. P. 1983. Novel methods of pest control. Proc. 6th Brit. Pest Control Conf. Cambridge. Published by Brit. Pest Control Assoc. London. Paper No. 6: 8pp.

Paper focuses on insect hormones as pesticides. The disadvantages of juvenile hormone insecticides such as methoprene are highlighted, especially their slowness, lack of adult insect kill and the fact that they prolong larval stages which may be a stage causing damage. References are made to research on anti-juvenile hormones by the author and others, especially against Lepidoptera. Such hormones would attack larval stages but none are commercially available.

FEAKINS, P. G. 1972. Special aspects of operations. A safe new organophosphorus insecticide for house fly and clothes moth control. Proc. 3rd Brit. Pest Control Conf., St. Helier 5-8 Oct. 1971: 137-43.

FUNDER, J. V. 1972. Testing of insecticides in the laboratory. Insecticides for fly control. Insecticides against textile pests. Insecticides against grain and storage pests. In: Danish Pest Infestation Laboratory Annual Report, 1971. Danish Pest Infest. Lab., Lyngby, Denmark: 25-27.

Evaluations of a new dichlorvos generator, synergized bioallethrin and tetramethrin, and new dimethoate formulations for fly control; fabric impregnants for dermestid control; and non-insecticide dusts for control of cockroaches, granary weevils, and flour moths are reported.

GARDNER, B. G., et al. 1964. Insecticidal activity and structure of some organotin compounds. Bull. Entomol. Res. 55(1): 17-21.

Triphenyltin compounds ineffective contact insecticides, most were effective moth-proofing agents; Tributyltin oxide gave 100% mortality to Tineola by contact.

GILLENWATER, H. B., et al. 1972. Gas-propelled aerosols and micronized dusts for control of insects in aircraft. 4. Potential for controlling stored-product insects. J. Econ. Entomol. 65(5): 1450-53.

Various dusts and aerosols were tested against Attagenus megatoma, Trogoderma inclusum, and T. glabratum in truck vans and aircraft. Formulations of 40% chlorpyrifos and a dust mixture of 13.3% chlorpyrifos plus 8.5% resmethrin, and 21.3% propoxur were the only formulations killing all of the insects. However, considering mammalian toxicity, dusts of 44.8% bromophos, 80% gardona, or a mixture of 7% d-trans-allethrin plus 40% gardona were most promising. The best aerosol was 7.5% resmethrin.

GOWERS, S. L. and G. N. J. LE PATOUREL. 1984. Toxicity of deposits of an amorphous silica dust on different surfaces and their pick-up by Sitophilus granarius (L.) (Coleoptera: Curculionidae). J. Stored Prod. Res. 20(1): 25-29.

Dried deposits of a silica dust from an aqueous solution applied to vinyl surfaces and loose dust deposits on glass proved highly toxic to adult grain weevils. The maximum amount of the dust picked up from the surfaces within 24 hours was not correlated with deposit toxicity. The results suggest that rate of exchange of dust between insect and surface was found to be of greater importance in determining toxicity.

HARRIS, R. L. N., et al. 1971. Inhibition of clothes moth (Tineola bisselliella) feeding with thioureas. J. Text. Inst. 62(12): 700-02.

HIGHLAND, H. A., et al. 1973. Synthetic pyrethroids as package treatments to prevent insect penetration. J. Econ. Entomol. 66(2): 540-41.

Of the compounds resmethrin, tetramethrin and d-trans-allethrin, and pyrethrin, resmethrin gave the best protection against a wide variety of stored product pests.

HIGHLAND, H. A. 1974. The use of chemicals in processing and packaging of stored products to prevent infestation. Proc. 1st Int. Work. Conf. Stored-Prod. Entomol., Savannah 7-11 Oct: 254-60.

This report is concerned with chemicals used in food processing areas and in or on food packages to protect various commodities from contamination by stored-product insects. The treatment of storage areas for either bulk or packaged food by fumigants, residual treatments, or space treatments is excluded.

HOFFMAN, W. 1982. Federal focus - military considers permethrin for clothing treatment. Pest Control 59(4): 10.

This news column reports that permethrin treatment of military clothing is resistant to laundering, wear and weathering, non-toxic to man, odorless, and not persistent in the environment.

HOSKINSON, R. M., et al. 1970. Inhibition of clothes moth and carpet beetle feeding with quaternary heterocyclic compounds. J. Econ. Entomol. 63(3): 1011-12.

Diquat and paraquat effectively inhibited feeding of Tineola bisselliella on treated fabric. Carpet beetles were less affected by the compounds tested.

IKAN, R., et al. 1974. A novel method for controlling insects. In: Symposium on dispersion dynamics of pollutants in environment with special reference to pesticides. 3rd Int. Congr. Pestic. Chem., Helsinki 3-9 Jul: 401.

The use of fatty acids as insect control substances in stored foods is discussed. They are possible oviposition inhibitors of bruchids and dermestids.

ITO, T., Y. FUNAKI and C. HIROSE. 1976. Efficacy of insecticides against Lyctus powder-post beetle, Lyctus brunneus (Steph.). Botyu-Kagaku 41(3): 138-42.

Permethrin showed the highest preventive efficacy against attacks of the beetle among the three insecticides studied and treatment at 0.01% could protect sapwoods for 3 months.

JACOBSON, M., R. E. REDFERN and G. D. MILLS, Jr. 1975. Naturally occurring insect growth regulators: II. Screening of insect and plant extracts as insect juvenile hormone mimics. Lloydia, Cincinnati 38(6): 455-72.

Ethereal extracts prepared from larvae, pupae or eggs of 10 spp. of insects and from various parts of 343 spp. of higher plants were screened for juvenilizing effects against Tenebrio molitor and Oncopeltus fasciatus. Results are given and discussed.

JONES, F. W. 1983. Fiber-reactive insecticides for wool: derivatives of O,O-diethyl O-[4-[(2-hydroxyethyl)thio]phenyl] phosphorothionate. J. Agric. Food Chem. 31(2): 194-97.

Tests on compounds that are capable of covalent bonding to wool were evaluated for their insecticidal activity against the common clothes moth and the furniture carpet beetle. Compounds containing reactive groups capable of cross-linking the wool possessed excellent hydrolytic stability when reacted with the wool, but the insecticidal portion of the molecule was not readily accessible to the insect. Compounds exhibiting the best action contained either a 3-[(2-chloroethyl)sulfonyl]propionate ester group or a 3-(vinylsulfonyl) propionate ester group.

JONES, F. W. 1983. Fiber-reactive insecticides for wool: phosphorus ester of 4-[(2-hydroxyalkyl)thio]phenol. J. Agric. Food Chem. 31(2): 198-201.

Thirty-four organophosphorus esters of 4-[(2-hydroxyalkyl)thio]phenol were screened for their ability to protect wool against certain insects. These esters exhibited the greatest insecticidal activity when a n-propylthio group was attached to the phosphorus atom.

KIESS, A. 1981. Uses of insect growth regulators. Pest Control 49(4): 27-28.

Summarizes commercial uses of methoprene, including use against cigarette beetles and tobacco moths where a single application prevents adult insect emergence for more than four years.

KRAMER, K. J. and H. E. McGREGOR. 1979. Activity of seven chitin synthesis inhibitors against development of stored product insects. Environ. Entomol. 8(2): 274-76.

The most effective compound tested was a nitrophenyldichlorophenoxybenzamide derivative. It was inhibitory toward all species tested at less than 1 ppm, except for the angoumois grain moth.

LA BRECQUE, G. C., et al. 1968. Laboratory procedures. In: principles of insect chemosterilization by G. C. La Brecque, et al, Editors. Appleton-Century-Crofts, N.Y.: 41-98.

Screening; secondary tests, including feeding, residues, dipping, and topical applications; and numerous special tests involved in evaluating chemosterilants are described. A list of chemosterilants with the arthropod species they have been used against is given.

LA HUE, D. W. 1965. Evaluation of malathion, synergized pyrethrum, and diatomaceous earth as wheat protectants (from insects) in small bins. USDA Mktg. Res. Rep. 726: 13pp.

Malathion (57%, 1.5 pts/1,000 BU.) protected stored wheat against beetle damage for 12 months, followed by 1.0 pt. malathion, diatomaceous earth and synergized pyrethrum in effectiveness.

LA HUE, D. W. and C. C. FIFIELD. 1967. Evaluation of four inert dusts on wheat as protectants against insects .... in small bins. USDA ARS, Wash., D.C. Market. Res. Rep. No. 780: 24pp.

Insect infestation readily developed in untreated wheat and, to a lesser degree, in wheat 11 years older from a companion field-scale bin study. Two diatomaceous earths afforded protection in proportion to the dosage. All were superior to the standard application of malathion. Two silica aerogels gave generally unsatisfactory protection. Flour yielding capacity and break baking properties of wheat were not changed by the addition of the dusts. The mixing tolerance of flour from samples treated with diatomaceous earth did not change, but increases were noted in all other samples.

LANG, J. H., et al. 1972. Preliminary investigations of tetramethrin as a protectant of woolen cloth against damage by black carpet beetle larvae (Coleoptera: Dermestidae). J. Ga. Entomol. Soc. 7(4): 260-64.

Concentrations of tetramethrin in emulsion baths from 0.005 to 0.5% by weight. All treated fabric resisted damage by Attagenus megatoma larvae before cleansing and after 1 drycleaning. All treated samples except those at the lowest bath concentration were satisfactorily resistant to feeding damage through 15 months of aging.

LEESCH, J. G. and D. R. SUKKESTAD. 1983. Some fumigant properties of hexamethyl distannane against stored-product insects. J. Ga. Entomol. Soc. 18(3): 385-94.

The fumigant action of the organo-tin compound hexamethyl distannane was much more effective than methyl bromide against adults of Tribolium confusum and Lasioderma serricorne, and the late-stage larva of the black carpet beetle, when exposed in free space. When the chemical was used on grain masses, the control was also greater than with methyl bromide.

LOSCHIAVO, S. R. 1969. Effects of the antifeeding compound AC-24055 (4 -(3,3dimethyl-1-triazeno) (acetanilide) survival, development, and reproduction of some stored-product insects. J. Econ. Entomol. 62(1): 102-07.

Effective protection by adult mortality and ovipositional inhibition of six coleopterous species.

MACELJSKI, M. and Z. KORUNIC. 1972. A contribution to the knowledge of the mechanism of action of the inert dusts on insects. Zast. Bilja, Belgrade 23(117/18): 49-64.

Tests were conducted with dri-die SG 68 against Tribolium castaneum, Acanthoscelides obtectus, Sitophilus granarius and S. oryzae at various relative humidities. Dehydration and death was greatly affected by the RH. At 90-100% RH the insects regenerated the cuticular wax layer repairing the damage caused by 3 or 6 hour exposure to the desiccant.

MACELJSKI, M., Z. KORUNIC and M. DANON. 1974. Results of investigations of the properties, activity and application of physical insecticides - inert dusts. Agron. Glas., Yugoslavia 36(9-12): 481-91.

The biological activity of 32 different dusts on 10 different stored-product beetles was studied.

MALLIS, A., B. T. BURTON and A. C. MILLER. 1962. The attraction of salts and other nutrients to the larvae of fabric insects. J. Econ. Entomol. 55: 351-55.

Some of the salts attractive to clothes moth larvae are KCl, K_2HPO_4, NaCl and Na_2HPO_4.

McCALLUM DEIGHTON, J. 1978. Pirimiphos-methyl and other insecticides in the control of stored-product insects. Outlook Agric. 9(5): 240-45.

A number of insecticides are being considered for control of malathion-resistant pests of stored-products. Pirimiphos-methyl is effective against Coleoptera, Lepidoptera, and grain mites.

McDONALD, L. L., et al. 1972. Toxicity of five new insecticides to stored-product insects. J. Econ. Entomol. 65(2): 529-30.

Cigarette beetle adults, confused flour beetle adults, black carpet beetle larvae and Indian meal moth larvae were tested for susceptibility to new insecticides.

McGOVERN, T. P., O. F. BODENSTEIN, J. H. FALES and M. BEROZA. 1975. N,N-disubstituted N-aliphatic amides as repellents for four cockroach species. J. Med. Entomol. 12(2): 259-260.

Laboratory studies indicate potential of repellents in roach management.

McGOVERN, T. P., R. E. BRY and J. H. LANG. 1984. Insect repellents as moth-proofing agents: N-alkyl carboxamides of heterocylic amines against black carpet beetle larvae (Coleoptera: Dermestidae). J. Ga. Entomol. Soc. 19(1): 56-61.

Acyl derivatives of 2-methylpiperidine, 3-methyl piperidine, and 4-methyl-piperazine were highly effective as moth-proofing agents against the black carpet beetle. A list of the 35 chemicals evaluated are included.

METWALLY, M. M. and F. SEHNAL. 1973. Effects of juvenile hormone analogues on the metamorphosis of beetles Trogoderma granarium (Dermestidae) and Caryedon gonagra (Bruchidae). Biol. Bull., Woods Hole, Mass. 144(2): 368-82.

The metamorphosis of T. granarium and C. gonagra may be.deranged with as little as 0.000005 microg and 0.05 microg respectively of certain juvenile hormone analogs. The effects of the juvenile hormone analogs on each species and the development of adult/larva/pupa intermediates are discussed.

MIESCH, M. D. 1964. Ecological and physiological mechanisms influencing food finding in Blattaria. PhD Thesis, Oklahoma State Univ., Stillwater, Ok.

A semi-solid bait of dehydrated potatoes, sucrose and water was the most attractive material for German cockroaches.

MILNE, D. L. 1963. A study of the nutrition of the cigarette beetle, Lasioderma serricorne (F.) (Coleoptera: Anobiidae) and a suggested new method for its control. J. Entomol. Soc. S. Afr. 26(1): 43-63.

Sorbic acid added to tobacco and maize meal, respectively, reduced population of L. serricorne and Tribolium confusum, respectively, by suppressing vitamin-synthesizing bacterial symbionts of these insects.

MILNE, D. L. 1964. Food preservatives as insecticides against Tribolium confusum Duval, T. castaneum (Herbst), and Lasioderma serricorne (F.). S. Afr. J. Agric. Sci., Pretoria 7(1): 79-85.

Action due to suppression of the vitamin-synthesizing micro-organisms. Death due to vitamin deficiency. Sorbic acid and benzoic acid were effective against Tribolium. Sorbic acid moderately effective in cut tobacco against cigarette beetle.

O'LOUGHLIN, G. J. 1982. Fiber-reactive insect-proofing agents for wool: phosphorus esters of 3-(hydroxymethyl)-4-nitrophenol. J. Agric. Food Chem. 30(6): 1056-60.

This report evaluates phosphorus esters as protection of wool fabric against the common clothes moth and the furniture carpet beetle. Results indicate that the compound when applied in a boiling dyebath covalently binds to the wool and then affords effective and durable insect-proofing against these two common textile pests.

PEKING WOOL MOTH-PRO, et al. 1975. An experimental study on the effect of phoxim on moths. ACTA Entomol. Sin., Peking 18(4): 367-73.

Phoxim effectively killed moths on woolen fabrics without damaging the fabrics. Moth larvae studied were Attagenus piceus, Trogoderma persicum, and Tineola bisselliella.

PENCE, R. J. 1963. The antimetabolite, imidazole, as a pesticide. J. Econ. Entomol. 56(1): 1-7.

Imidazole found effective contact insecticide experimentally against silverfish, cockroaches, termites, bedbugs, fleas, flies, mosquitoes, ticks, spiders and mites.

PENCE, R. J., et al. 1966. Inhibition vs. excessive use of Vitamin K and other nutrients for the control of carpet beetles. Residue Rev. 12: 45-64.

Antimetabolites and excesses of essential nutrients afford a safe approach to pest control; Vitamin K is inhibited by both dicumarol and salicylic acid.

PRATT, J. J., Jr., et al. 1972. Insect control strategies based on nutritional principles: a prospectus. In: Insect and mite nutrition. North-Holland Publ. Co., Amsterdam: 651-68.

The possibility exists of developing strategies for controlling insects in certain human foods by developing nutritional faults detrimental to insects but harmless to humans.

QUISTAD, G. B., D. C. CERF, D. A. SCHOOLEY and G. B. STAAL. 1981. Fluoromevalonate acts as an inhibitor of insect juvenile hormone biosynthesis. Nature, London. 289: 176-77.

A compound is described which produces precocious pupation in Lepidoptera. This would abbreviate the feeding (larval) stage of moths and prevent viable adults developing.

SCHOFIELD, E. K. and S. CRISAFULLI. 1980. A safer insecticide for herbarium use. Brittonia 32(1): 58-62.

Pyrethrins, the active ingredients of the insecticide pyrethrum, are very effective in killing insects but are harmless to mammals. When combined with silica gel to form drione powder, they can be applied inside herbarium cases for long-term protection against insects. Preliminary tests at the New York Botanical Garden (USA) have shown that drione powder or aerosol spray readily kills anobiid beetles. Drione has potential as a safer alternative to dangerous chemicals used in the past.

SCHWARTZ, M., O. F. BODENSTEIN and J. H. FALES. 1970. Compounds related to cyanoacetic acid as repellents for cockroaches. J. Econ. Entomol. 63(2): 429-32.

Laboratory studies indicate potential of cockroach repellents for cockroach management.

SPEIRS, R. D. and L. L. McDONALD. 1975. Contact, residue, and vapor toxicity of new insecticides to stored-product insects. III. USDA ARS Market. Res. Rep. No. 1039: 14pp.

Seventeen new insecticides were tested against Tribolium confusum adults and Attagenus megatoma larvae.

SU, H. C. F. 1984. Comparative toxicity of three peppercorn extracts to four species of stored-product insects under laboratory conditions. J. Ga. Entomol. Soc. 19(2): 190-99.

Two acetone extracts of unripe fruit of Piper nigrum (black pepper and green peppercorn) and a hexane extract of dry fruit of Piper guineense (West African or Ashanti pepper) were found to have toxicological properties against 4 species of stored-product pests (the cowpea weevil, rice weevil, cigarette beetle, and confused flour beetle) when applied to crops in storage. The order of decreasing toxicity was black pepper greater than green peppercorn greater than West African pepper.

TAYLOR, R. W. D. and N. J. EVANS. 1982. Laboratory evaluation of four insecticides for controlling Dermestes maculatus (DeGeer) on smoke-dried fish. Int. Pest Control 24(2): 42-45, 49.

The ability of 4 insecticidal compounds to control dermestids on smoked fish is reported. Residual levels of the pesticides were monitored and evaluated at different concentrations and over a specific time period. Pirimphos-methyl at 0.0125% concentration gave the best protection over a longer storage period. Residue levels were observed to decrease significantly during storage at 27°C.

TITTANEN, K. 1971. The efficiency of a pyrethrins aerosol against the larvae of the clothes moth (Tineola bisselliella). Pyrethrum Post 11(1): 15-17.

The efficiency and residual life of aerosols containing pyrethrins and aerosols containing DDT and lindane were about equal when applied to woolen fabrics for protection against T. bisselliella.

UDOWSKI, P., et al. 1967. Growth inhibition of Dermestes maculatus by phytosterols. J. Nutr. 91(2 pt.1): 201-07.

VARDELL, H. H. 1984. Potential of seven insecticides for stored-product insects control. J. Ga. Entomol. Soc. 19(1): 138-41.

The most toxic insecticide tested on the black carpet beetle and Trogoderma variable was cypermethrin. Fenitrothion was the most toxic to T. glabrum. Tetramethrin and d-trans-allethrin were the least toxic to the tested species.

WAL, Y. C., S. L. PERTI and P. N. AGARWAL. 1971. Use of antimetabolites for protection of woolen textiles against insect attack. Labdev. J. Sci. Technol., Part B Life Sci., Kanpur 9(3): 212-20.

Woolen fabrics treated with imidazole, an antimetabolite of nicotinic acid, resist insect attack even when drycleaned 6 times. The feasibility of using antimetabolites for the protection of woolen textiles against insect attack is discussed.

WEST, A. S., et al. 1981. Canadian Forces Manual on Pest Control. 4th Edition. Dep. Natl. Def., Ottawa: 338pp.

A detailed pest control manual prepared specifically for use by the Canadian Armed Forces. Included in this text are the ways to detect infestations of insects and other pests, follow-up surveys, selection and application of control methods with emphasis on integrated pest management where applicable.

WOODROFFE, G. E. 1965. The sterol requirements of several species of Dermestes (Coleoptera: Dermestidae). Proc. 12th Int. Congr. Entomol. (London, 1964): 625.

Diet rich in sterols cause deformed progeny or retarded development producing mortality.

WOODROFFE, G. E. and C. W. COOMBS. 1979. The development of several species of Dermestes (Coleoptera: Dermestidae) on various vegetable foodstuffs. J. Stored Prod. Res. 15(3/4): 95-100.

Dermestes frischii, D. haemorrhoidalis, D. peruvianus, D. ater and D. lardarius were reared on cocoa, copra, almonds, ground nuts, whole wheat flour, wheat-germ, fishmeal or fishmeal and yeast. The different species developed to different degrees on the various foodstuffs. The results are discussed in relation to the sterol content of the foods and the sterol requirements of the species.

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PART II: SECTION 10

USE OF CONVENTIONAL CHEMICALS IN NON-CONVENTIONAL WAYS

Various insecticides (including pyrethrum, malathion and lindane) and an antifeedant have proved effective in tests against stored product pests when incorporated in cotton bags, paper bags or cardboard boxes used for storage or transportation of vulnerable items (see annotated bibliography for further information). Newer chemicals, such as long-lasting pyrethroids (e.g. permethrin), might be even more effective and this could be a useful avenue of research. Clearly the use of insecticidal boxes and wrapping materials could help prevent new infestations or cross infestations during transit.

Other uses of insecticides as impregnants or coatings include their use in shelf paper for shelves and for lining drawers. Until recently such paper was treated exclusively with lindane, but now it is possible to obtain paper treated with bendiocarb insecticide. Where concern exists over the safety of lindane, clearly it would be wiser to use bendiocarb treated paper. These shelf papers kill pests which walk on them and they work for six months or more. Although they are aimed primarily against cockroaches, they will kill other crawling insects too.

Another unusual use of conventional pesticides is their incorporation in insecticidal paints, lacquers and varnishes. Commercially available insecticidal varnishes contain 1% or 2% chlorpyrifos (Killmaster® trademark) and when applied to structural surfaces they kill insects which crawl on them. The labels for these products claim they work for six months to one year but in dry, dark situations they can last much longer. Currently, these varnishes are mostly used in commercial kitchens against cockroaches but they can be used in museums against a range of crawling pests. As with other varnishes, there are certain surfaces where they should not be applied, either because they cause solvent damage (e.g. on plastics) or because they do not adhere well (e.g. on glass or ceramic tile). These varnishes are particularly useful when applied to the legs of tables, etc. to kill any insect which tries to climb up from the floor.

Lastly, conventional insecticides can be incorporated in insecticidal adhesive tapes which are stuck on surfaces which insects are expected to walk on. As the insects cross the tape they pick up insecticide from the surface and die. Commercially available tapes contain the carbamate insecticide propoxur (Hercon® Roach Tape) and they are designed like a sandwich, with the lower side being adhesive, the middle holding a reservoir of propoxur and the upper surface being a protective layer coated with a layer of propoxur. As this top layer of propoxur is removed by insects it is replaced by migration of more propoxur from the reservoir beneath. The use of such tapes allows precise application of insecticide without any problems of drift from sprays or dusts. However, they are expensive and time consuming to use.

It is perhaps worth pointing out that the technology clearly exists to impregnate the surfaces on which entomological collections are mounted, so that they are rendered insect-proof.

BIBLIOGRAPHY

SECTION 10 - Use of Conventional Chemicals in Non-conventional Ways

(e.g. impregnated packaging or tapes)

JOSHI, H. C., et al. 1965. Studies on the protectivity of jute bags impregnated with organic insecticides against red flour beetle and cigarette beetle. Indian J. Entomol., New Delhi 27(4): 491-93.

DDT plus BHC (1:1) and malathion gave more than 80% protection at the end of 3 months against Lasioderma serricorne and Tribolium castaneum.

KYDONIEUS, A. F., A. R. QUISUMBING, I. K. SMITH, S. BALDWIN and R. A. CONROY. 1976. Hercon technical bulletin. No. 26. 4pp.

Manufacturers report of 100% kill (after three days) of German cockroaches after a two second contact with roach tape impregnated with propoxur.

LAUDANI, H. 1958. Insect infestation of packaged commodities and its prevention. Feedstuffs 30(3): 14-16.

Evaluation of full-seam overlap and staggered satchel-bottom in multiwalled bags; also, use of synergized pyrethrum and chlorinated hydrocarbon treated bags.

LAUDANI, H., et al. 1955. A laboratory method of evaluating the repellency of treated paper to stored-product insects. Tappi 38(6): 336-41.

Continuous exposure of adult flour beetles for 5 days on an arena composed of equal areas of treated and untreated paper.

LAUDANI, H., et al. 1958. A new method for using lindane crystals for protecting boxed woolens against fabric-insect damage. Agric. Market Serv. USDA Special Rpt. B-113, Stored Products Insects Sect. BS 1-56: 7pp.

Method of adhering the crystals to sheets of paper fiberboard by adhesive.

LAUDANI, H., H. A. HIGHLAND and E. G. JAY. 1966. Treated bags keep corn meal insect-free during overseas shipment. Am. Miller Process., U.S. 2: 6pp.

The effectiveness of the insect-resistant bags (pyrethrum + piperonyl butoxide) was evident throughout the entire test period. The average number of insects present after 1 month in the untreated bags was 4512 as compared with less than one in the insect-resistant bags.

LOSCHIAVO, S. R. 1970. 4'(3, 3-dimethyl-1-triazeno) acetanilide to protect packaged cereals against stored products insects. Food Technol. 24(4): 181-85.

The antifeeding compound was effective in preventing infestations of Tribolium confusum, Oryzaephilus surinamensis, Rhyzopertha dominica, and Trogoderma parabile when used in connection with heat-sealed polyethylene bags, plastic laminate pouches and cotton bags of certain weaves.

QURESHI, A. H. 1966. Toxicity and persistence of an emulsion paint containing gamma BHC to some stored products insect pests. Nigerian Stored Prod. Res. Inst. Annu. Rpt.: 129-31.

Sitophilus zeamais did not come into contact with treated wall surfaces often enough to pick up a lethal dose. Tribolium sp. from northern Nigeria were resistant to lindane.

SMITH, L. W., Jr., J. SIMKIN and H. A. BOHM. 1981. Development of effective, safe insect resistant treatment which can be applied or incorporated into food packaging materials. US Army Natick Res. Develop. Lab., Tech. Rep. Oct. Fel: 19pp.

Samples of paper treated with microencapsulated formulations of synergised pyrethrum or synthetic pyrethroids were tested for repellency against adult Tribolium confusum and Trogoderma variable.

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PART II: SECTION 11

USE OF PHEROMONES

Pheromones are chemicals secreted by insects in order to modify the behavior of other insects belonging to the same species. They include sex attractants, aggregation pheromones and pheromones which stimulate mass attack or feeding, or which mark territory boundaries. For pest management purposes, natural pheromones extracted from insects or synthetic pheromones and pheromone mimics can be used.

Sex pheromones and aggregation pheromones have been the prime objects of study, and their role in insect communication relates to the longevity and feeding requirements of adult insects. Adults which are short-lived (less than one month) and require no feeding for reproduction, rely on sex pheromones for communication. These insects include moths, anobiid and dermestid beetles, and their sex pheromones are usually produced by the female to attract males.

Long-lived adults which need to feed for reproduction rely on male-produced aggregation pheromones for long distance communication. These insects include grain and flour beetles and both males and females respond to the aggregation pheromone. German cockroaches also produce an aggregation pheromone and this attracts males, females and nymphs. The effect of such aggregation pheromones is to attract insects so that feeding and/or breeding can take place.

Alongside pheromone research has been the development of traps in which pheromones (or other attractants) can be placed. These traps serve to hold the insects for later inspection or disposal and they also help protect and extend the life of the pheromone. The type of pheromone and type of trap in which it is used must be adjusted to the target species. To date the pheromones and traps which are commercially available are aimed against food pests (e.g. flour and grain beetles and flour moths). However, for many pests of museums, including carpet beetles, pheromones have been identified and they could be manufactured and become commercially available with corresponding traps if there was a demand.

As with other traps, pheromone traps must be placed correctly. They can be placed where there is a history of infestation, or in receiving areas or in transportation vehicles to monitor for new infestations. In large areas, large numbers of traps can be placed in a grid pattern at intervals of 25 to 50 feet. Then, as catches occur, the grid can be tightened to pinpoint problem areas. The particular source of infestation can then be confirmed by visual inspection. Each pheromone trap should be placed in locations likely to be sought by the target insects and sheltered from physical disturbance. In general, pheromone traps should be placed away from doors and windows to avoid luring insects into a building from outside.

Traps based on pheromones need routine servicing to replace exhausted attractants. Most pheromones in commercial use need monthly replacement. (Food attractants are usually effective for one to two months and inorganic attractants, such as salts, may last indefinitely but are only effective at close quarters.)

Pheromone traps are especially useful for early detection of an infestation, and this enables better targeting of treatments and less use of pesticides. In some cases, mass trapping using pheromone traps could achieve a useful level of control. This might be particularly applicable for species in which males emerge before females, so that all the males could be trapped before any females were available to compete with sex-attractant traps (e.g. black carpet beetle).

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BIBLIOGRAPHY

SECTION 11 - Use of Pheromones

ANONYMOUS. 1983. Checking out those stored product pests. Pest Control 51(11): 28, 30, 32, 50.

A general article outlining the use of pheromones and other attractants for early detection of stored product pests. Based on the work of Wendell Burkholder at the Stored Product and Household Insects Laboratory, University of Wisconsin, Madison. Burkholder is the leading researcher in the pheromone field and his discoveries have been commercialized by Zoecon Corp. of Palo Alto, Calif.

BARAK, A. V. and W. E. BURKHOLDER. 1976. Trapping studies with dermestid sex pheromones. Environ. Entomol. 5(1): 111-14.

Traps treated with the pheromones, megatomoic acid, caught significantly more target insects when compared to control traps.

BARAK, A. V. and W. E. BURKHOLDER. 1978. Interspecific response to sex pheromones, and calling behavior of several Attagenus species (Coleoptera: Dermestidae). J. Chem. Ecol., N.Y. 4(4): 451-61.

Interspecific pheromone responses were tested, with A. megatoma megatoma, A. M. canadensis, A. M. japonicus, and A. schaefferi spurcus showing equal cross responses. Attagenus rufipennis, bicolor, and elongatulus males responded only to female extracts of their own species.

BELL, W. J. 1984. Bionomics and control of the American cockroach. Pest Management 3(3): 12-19.

Addition of a sex pheromone to conventional insecticides (propoxur and chlorpyrifos) greatly increased the kill of American cockroaches in both laboratory and field trials. Use of the sex pheromone offers the potential for achieving greatly improved control of this species of cockroach with very small amounts of insecticide to which the cockroaches are attracted. Many references to related research.

BELL, W. J., J. FROMM, A. R. QUISUMBING and A. F. KYDONIEUS. 1984. Attraction of American cockroaches to traps containing periplanone B and to insecticide-periplanone B mixtures. Eviron. Entomol. (in press).

Trials in the Philippines showed that many more American roaches were captured by sex pheromone baited traps than by unbaited traps.

BLUM, M. S. 1977. Insect pheromones. In: Pesticide chemistry in the 20th Century by J. R. Plimmer, Editor. Am. Chem. Soc., Wash., D.C. ACS Symp. Ser. No. 37: 209-36.

A comprehensive overview of insect pheromone technology is presented. Chemistry of insect pheromones related to the major orders, and the various responses that insects exhibit to pheromones are included.

BURKHOLDER, W. E. 1970. Pheromone research with stored-product coleoptera. In: Control of insect behavior by natural products by David L. Wood, et al., Editors. Acad. Press, New York: 1-20.

Pheromones from Trogoderma, Attagenus; interspecies attraction.

BURKHOLDER, W. E. 1973. Black carpet beetle: reduction of mating by megatomoic acid, the sex pheromone. J. Econ. Entomol. 66(6): 1327.

BURKHOLDER, W. E. 1976. Application of pheromones for manipulating insect pests of stored products. In: Proceedings of a symposium on insect pheromones and their applications, Nagaoka and Tokyo, December 8-11, 1976. Natl. Inst. Agric. Sci., Nishigahara, Kiat-Ku, Tokyo: 111-22.

The possible use of sex pheromones in traps treated with malathion or pathogenic protozoa are being studied as control and survey techniques for Trogoderma, Attagenus, and some pyralid moths.

BURKHOLDER, W. E. 1982. Reproductive biology and communication among grain storage and warehouse beetles. J. Ga. Entomol. Soc. 17(4): 1-10.

Two general types of communication and reproductive strategies of stored-product beetles are reported. The short-lived beetles generally produce sex pheromones and have a highly-synchronized communication system with daily activity rhythms. They usually do not feed as adults. The long-lived beetles have male-produced aggregation pheromones and require food for pheromone production and egg maturation. The aggregation pheromone is a signal that food is present and leads to mating encounters. Many of the pheromones are identified and are available commercially.

JACOBSON, M., et al. 1970. Sex pheromones of the lepidoptera. Recent progress and structure-activity relationships. In: Chemicals controlling insect behavior by Morton Beroza, Editor. Acad. Press, New York: 3-20.

KYDONIEUS, A. F., M. BEROZA and G. ZWEIG. 1982. Insect suppression with controlled release pheromone systems. Volume I. CRC Press Inc., Boca Raton, Fla.: 274pp.

Vol. I of this two volume series covers fundamental concepts, formulations, methods and application pheromones in insect monitoring and suppression programs.

KYDONIEUS, A. F., M. BEROZA and G. ZWEIG. 1982. Insect suppression with controlled release pheromone systems. Volume II. CRC Press Inc., Boca Raton, Fla.: 312pp.

The application of pheromones in mass trapping, mating disruption and other pest management strategies is discussed for a number of agricultural and forest pests. A useful list of insect attractants, pheromones and related compounds available for research is provided in Chapter 15.

MUELLER, D. K. 1982. Pheromones. New weapon against stored product insects. Pest Control 50(2): 22, 24.

The potential uses of pheromones in the control and detection of stored product pests is briefly discussed.

MUELLER, D. K. 1982. Pheromones - Part 2. Their use as a surveillance tool. Pest Control 50(3): 26, 28, 31.

The use of pheromones to detect and monitor populations of stored product pests is reviewed. Potential for control is also discussed.

SCHNEIDER, B. 1984. Understanding cockroach repellency. Pest Control Technol. 12(8): 44, 46, 50, 51.

Repellent active ingredients, solvents or other additives in insecticides may result in cockroaches avoiding treated areas. The problem is worst when treatments are incomplete, allowing cockroaches to move to untreated harborages. Use of low repellency insecticides or more thorough treatment of roach harborages produces better control. The use of attractant cockroach pheromones combined with insecticides achieves better results than using the insecticide alone.

SHOREY, H. H. and J. J. McKELVEY, Jr. 1979. Chemical control of insect behavior. Theory and application. John Wiley and Sons, New York: 414pp.

This book deals primarily with chemicals that insects perceive by smell and which constitute their most important stimuli when they are at a distance from the source of chemical. Secondarily, it considers taste substances which are perceived by insects when in contact with the source. Each chapter is written by an expert in the field. A wide variety of topics are covered in the field of insect sensory physiology, behavior, chemical ecology, and pest management.

SILVERSTEIN, R. M. 1970. Attractant pheromones of coleoptera. In: Chemicals controlling insect behavior by Morton Beroza, Editor. Acad. Press, New York: 21-40.

Natural and synthetic pheromones of Ips confusus, Dendroctonus frontalis, D. brevicomis, D. ponderosae, Attagenus metatoma, Trogoderma inclusum, and Limonius californicus are discussed.

SILVERSTEIN, R. M. 1970. Methodology for isolation and identification of insect pheromones - examples from coleoptera. In: Control of insect behavior by natural products by David L. Wood, et al., Editors. Acad. Press, New York: 285-99.

Includes data on Attagenus megatoma.

SILVERSTEIN, R. M., et al. 1967. Sex attractant of the black carpet beetle. Science 157(3784): 85-86.

Isolation, identification and synthesis of tetradecadienoic acid.

SILVERSTEIN, R. M. and J. C. YOUNG. 1976. Insects generally use multicomponent pheromones. In: Pest Management with Insect Sex Attractants by M. Beroza, Editor. Am. Chem. Soc., Wash., D.C. ACS Symp. Ser. 23: 1-29.

A discussion of the identification of multicomponent pheromones that affect insect behavior. A list of insect families identified as having multicomponent pheromones is included, and the information is referenced to the bibliographic source.

SMITH, L. W., Jr. and W. E. BURKHOLDER. 1981. Biomonitoring for stored-product insects of military importance and a review of the literature and military application. US Army Natick Res. Develop. Lab., Tech. Rep. Dec XXXX Fel: -.

This article reviews current technology and the practical use of insect pheromone traps in the military warehouse environment. The recognition, identification, synthesis and bioassay of insect pheromones is discussed with respect to 18 kinds of stored product insects. A list is given of insect pheromones available for the detection and control of stored product pests.

SMITH, L. W., Jr., W. E. BURKHOLDER and J. R. PHILLIPS. 1981. Detection and control of stored food insects with traps and attractants (Part II - the effect of pheromone-baited traps and their placement on the number of Trogoderma species captured). US Army Natick Res. Develop. Lab., Tech. Rep. XXXX - Fel: 15pp.

Pheromone-baited traps were successful in capturing Trogoderma adults in military warehouses. More beetles were trapped near exterior walls with doors than in any other location in one warehouse but not another. Significant differences could not be shown with regard to effect of trap height.

SMITH, L. W., Jr., T. J. SHAPAS and W. E. BURKHOLDER. 1981. Detection and control of stored food insects with traps and attractants (Part I - development of the pheromone trap and an apparatus for measuring the release rate of pheromones). US Army Natick Res. Develop. Lab., Tech. Rep. XXXX - Fel: 14pp.

An inexpensive trap showed favorable preliminary results in sampling laboratory and field populations of Trogoderma larvae and adults when baited with appropriate attractants, plus DDVP/Vapona to kill attracted insects.

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USE OF COMBINATIONS OF METHODS IN INTEGRATED PEST MANAGEMENT (IPM) PROGRAMS

The focus on Integrated Pest Management (IPM) in the past few years has often given the mistaken impression among the uninformed that IPM is a new concept. This could not be further from the truth. Combinations of farming practices such as crop rotation, careful timing of sowing, irrigation, hand weeding or hand removal of bugs or sick plants, represent an integrated approach to maximizing crops and minimizing pests. Likewise, in pest control in buildings, for generations there have been programs based on combinations of measures, including pest exclusion, sanitation, sealing of vulnerable items in protective cases and caulking of pest harborages, as well as use of traps and chemicals. What is relatively new is the reliance on pesticides, and this arose out of the development of "modern" pesticides in the 1940s which held the promise of solving all pest problems.

We now know that no single pesticide is a panacea and the focus on IPM programs is really a return to basics. A modern IPM program is no different in its principles from IPM programs implemented 50 years ago. Today we simply have a wider variety of materials and methods that we can incorporate into an IPM program. The preceding sections of Part II indicate the range of options available as components of an IPM program. In Part I, some of these options were suggested for use against particular pests. Clearly, there is no single correct program for dealing with a particular pest. Each situation is different and the programs must be customized accordingly. Nonetheless, there are certain steps that will be common to any IPM program and these steps fall into the following five categories:

(a) Inspection

(b) Diagnosis and reporting

(c) Planning of the pest management strategy

(d) Implementation of the strategy

(e) Evaluation of results

These categories are listed in the sequence they would be carried out, but in practice it is a cyclical series rather than a linear series.

Following the evaluation of results [category (e)] a new inspection would be conducted, and so on. Inevitably the diagnosis and consequent strategy in future cycles will be different than in past cycles because the pest situation will have changed, and some of the environmental factors which affect the pest potential will have changed. For instance, a program aimed at killing a mouse infestation in a building may result in mouse carcasses in wall voids which might serve as future breeding grounds for blowflies or dermestid beetles. It is in the anticipation of such changes, and in the understanding of the dynamic interrelationships between pests and environmental factors that the real skill in pest management lies.

To illustrate the multi-component nature of an IPM program for museums, the following example from an actual museum is outlined. In this museum insect damage was noted in tapestries in a ground-level gallery housing medieval furniture and tapestries. Inspection of the gallery and adjoining areas revealed numerous factors conducive to pest entry and survival, and there was an active infestation of black carpet beetles inside the gallery and in birds' nests outside. Recommendations for dealing with this infestation and for minimizing future occurrences are summarized in the table below:

COMPONENTS OF AN INTEGRATED PEST MANAGEMENT PROGRAM
AIMED AGAINST BLACK CARPET BEETLES IN A TAPESTRY GALLERY

TYPE OF APPROACH	*ACTION SUMMARY*
<u>CULTURAL</u>:	
a) Cleaning	• Regularly remove lint accumulations from crevices and floor registers. • Regularly remove birds' nests, feathers, etc. from exterior ledges and gutters. Destroy birds' nests every 14 days in spring to prevent establishment on the building. • Remove leaf debris from gutters and drains around building. • Surface clean tapestries by vacuuming or gentle brushing to remove beetle eggs. • Provide trash receptacles in the gallery and service them daily.
b) Temperature control	• Reduce the summer temperature of gallery. • Avoid over-heating the gallery in winter.

Continued over ....

TYPE OF APPROACH	*ACTION SUMMARY*
CULTURAL continued	
c) Flowers and grounds management	• Replace organic mulches (e.g. bark) by stone mulches in the museum grounds. • Remove planters from the museum (or treat them against pests). • Minimize use of flowering plants in the museum grounds (or treat them against pests). • Stop use of cut flowers for ornamenting the museum (or treat them before they are brought in). • Discourage feeding of pigeons and sparrows in the museum grounds.
d) Lighting	• Minimize exterior lighting. • Convert essential exterior lighting from standard lamps to sodium vapor lamps.
<u>MECHANICAL:</u>	
a) Exterior doors	• Fit gaskets, sweeps, etc. as appropriate to minimize insect entry through crevices around doors. • Fit self-closing devices to minimize the time that doors are open.
b) Windows	• Caulk around window frames. • Keep unscreened windows shut. • Fit screens to windows which are opened (a minimum of 20 mesh screen will exclude carpet beetles).
c) Air vents	• Fit screens to vents in the walls and roof. (Note: consult with a ventilation engineer to check whether the air flow rate needs adjustment to accommodate the resistance imposed by the screens.)
d) Eaves & Ledges	• Screen eaves with wire mesh to exclude birds. • Protect ledges with spikes to prevent birds alighting.

Continued over ....

TYPE OF APPROACH	*ACTION SUMMARY*
MECHANICAL cont'd. e) Wall crevices	• Seal interior wall crevices to deny egg laying or pupation sites to insects. • Seal exterior cracks and crevices in walls to prevent insect access (weep holes can be screened).
TRAPPING:	• Place sticky traps under heavy furnishings. • Place sticky traps inside floor registers. • Place sticky traps on ledges near gallery ceiling. • Place sticky traps discretely on each side of tapestries. Note: The purpose of these traps is to monitor insects in the gallery. They should be replaced monthly.
CHEMICAL: a) Fumigation	• Fumigate the gallery using sulfuryl fluoride (Vikane®). Note: Alternatively the tapestries can be individually fumigated in-place by enclosing them in plastic sheeting taped to the walls on which they hang. However, this will not kill reservoirs of pests in crevices and furnishings in the rest of the gallery.)
b) Use of residual insecticide sprays	• Spray the footings outside the gallery using a fan spray of 0.5% Ficam® W every two months from the end of April to the end of September. • Spray around exterior doorways to the gallery using a fan spray of 0.25% Ficam Plus every two months from the end of April to the end of September. • Spray the interior thresholds with 0.25% Ficam Plus or Dursban® L.O. every two months throughout the year.

Continued over ....

TYPE OF APPROACH	ACTION SUMMARY
CHEMICAL (b) continued	• Paint the inside surface of the air ducts under the floor registers with insecticide lacquer (Killmaster®), once a year in the spring. • Spray the lower six to 12 inches of the walls with 0.5% Ficam W every three months (avoid splashing or runoff onto the wooden floor to prevent marring the wax finish). • Inject the crevices between the walls and floor and any other structural crevices, with 0.5% Dursban L.O. (using a compressed air sprayer with a crevice-injection attachment) every three months throughout the year. Use a spray pressure no higher than 10 p.s.i.
c) Use of residual insecticide dusts	• Inject Ficam Dust into exterior wall crevices and weep holes in spring and fall. • Blow Ficam Dust through floor vents exhausting to the exterior in the spring. • Dust flowering plants in the grounds with Sevin® as required to kill carpet beetles on flower heads.
d) Use of residual insecticide granules	• Sprinkle 0.5% Dursban granules on the ground along the exterior of the gallery every two months from the end of April to the end of September. • Sprinkle 0.5% Dursban granules inside planters every two months throughout the year.
e) Use of non-residual space sprays	• Fit automatic pyrethrum aerosol dispensers in the exterior lobbies leading to the gallery to kill or repel flying insects. • Treat cut flowers with a hand-held pyrethrum aerosol before they are brought into the museum.

Once again, however, it must be stressed that for different pests in different situations the components of an IPM program would be quite different. For instance, in the above example it was preferred that the tapestries remain in-place and not be fumigated in a chamber. Further, the choice of insecticides for use inside the gallery was partly dictated by the nature of the surfaces to which they would be applied (in this case, white plaster walls and waxed wooden floors) and by the need to avoid lingering insecticide odors.

Finally, it is worth pointing out that one traditional aspect of IPM programs has been made redundant by modern technology, at least in some indoor situations. This is the concept of "acceptable levels" of pests. In agricultural and horticultural IPM programs it is usually uneconomical and often impractical to eliminate all pests. Hence the crop is monitored until an agreed threshold or action-level of pests is attained. At this point, measures are taken to reduce the pest population. Thus the pest population is "managed" in order to keep it below the threshold level. Indoors, particularly in highly sensitive situations, such as research laboratories, the only acceptable level of pests may be zero. Therefore, increasingly, with our new knowledge of pest biology and new materials for monitoring and control, we are moving beyond IPM to an approach which may be called Integrated Pest Eradication or IPE.

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BIBLIOGRAPHY

SECTION 12 - Use of Combinations of Methods in IPM Programs

ANONYMOUS. 1965. Stored-tobacco insects; biology and control. USDA Handbook 233 (Rev.): 39pp. [ARS Stored-Prod.].

Chiefly cigarette beetle (Lasioderma serricorne) and tobacco moth (Ephestia elutella).

ANONYMOUS. 1967. Clothes moths and carpet beetles. Brit. Mus. (Nat. Hist.) Econ. Ser. 14: 1-15.

ANONYMOUS. 1967. Market Quality Research Division's Annual Progress Report and related work of the State Agricultural Experiment Stations. USDA ARS Market Quality Res. Div., Ann. Rep.: 1-147.

Research report on packaging, storage, rodent and insect barriers, repellents, biocontrol, traps, irradiation, ecology, stored products, and insecticides.

ANONYMOUS. 1969. Cigarette beetle. NPCA Tech. Rel. 3-69: 3pp.

The biology, life cycle, foods infested, and control are given.

ANONYMOUS. 1969. Drugstore beetle. NPCA Tech. Rel. 4-69: 2pp.

The biology, life cycle, foods and control are given.

ANONYMOUS. 1973. Shipboard pest control for food-service personnel. US Navy DVECC, Alameda, Calif.: 25pp.

Reviews pest control preparation, stored product pests, cockroaches, rodents, survey methods and control.

ANONYMOUS. 1974. The common furniture beetle. Build. Res. Establ., Princes Risborough Lab., Aylesbury Tech. Note (47): 14pp.

ANONYMOUS. 1975. The carpet beetles. NPCA Tech. Rel. 7-75: 4pp.

The article describes the four major carpet beetles, gives their biology, food habits, life cycle, and discusses their control.

ANONYMOUS. 1977. Mausoleum pests. NPCA Tech. Rel. ESPC 3(9): 205-10.

Not for distribution. The beetle and fly pests common to mausoleum or burial areas are described and their biology and control discussed.

ANONYMOUS. 1977. Questions on wood-destroying beetles. NPCA Tech. Rel. ESPC 5(2): 131-34.

Discusses the identification of beetle damage in wood, identifying active infestations, determining age of infestations and control. Not for distribution.

ANONYMOUS. 1979. Basic food plant sanitation manual. Third Edition. Am. Inst. Baking, Manhattan, Kans.: 255pp.

Topics covered include basic management principles, personnel training, laws and regulations, sanitation, inspections, pest control, pesticide use and safety, cleaning agents, food microbiology, and other public health aspects of food plant management.

ANONYMOUS. 1979. Guidelines for the control of insect and mite pests of foods, fibers, feeds, ornamentals, livestock, forests, and forest products. USDA SEA Handb. No. 554: 822pp.

USDA guide for entomologists and other research and extension workers for control of forest insects, stored product pests, household pests, mosquitoes, livestock pests, and crop pests. Issued April 1979. [Forest Service].

ANONYMOUS. 1980. Warehouse sanitation manual. Am. Inst. Baking, Manhattan, Kans.: 144pp.

This manual is designed to familiarize the reader with federal laws affecting food warehouse and distribution facilities. Guidelines are provided for implementing the elements of an effective in-plant sanitation program including organization and planning, personnel training, pest identification and controls, regulations, pesticide handling, and proper storage practices.

ANONYMOUS. 1982. Varied carpet beetle: Anthrenus verbasci (L.). Pest Manage. 1(4): 17-18.

A NPCA pest profile report which describes the varied carpet beetle, Anthrenus verbasci (L.). Included in the article are its life cycle, description and pest management techniques to combat this cosmopolitan pest. Proper focus is given on non-chemical methods, particularly cleaning and/or disposal of infested items.

BALLARD, J. B. and R. E. GOLD. 1984. Biology and management of wood and oriental cockroaches in the near environment. Pest Management 3(7): 20-25.

The authors review the literature and conclude that management of these cockroaches can be achieved by combinations of habitat modification (especially removal or sealing of harborages), use of conventional residual insecticides and trapping. Trapping alone has not been reported as being effective. Insecticide resistance has not been reported with these species.

BECKER, P. C. and W. BROCKMAN. 1982. Library pests. Pest Control 50(12): 43.

Brief overview of the damage and control of beetles, booklice, silverfish, termites, cockroaches, and brown house moth in books. Environmental adjustments as well as pesticides are recommended. The article suggests that little damage to books or the environment will result from use of ethylene oxide, boric acid, silica gel, resmethrin or PDB.

BENNETT, G. W. and J. M. OWENS, Editors. 1985. Advances in urban pest management.

15 chapters, each by different authors who are eminent in their field, draw together information on the balanced use of cultural, biological and chemical measures that are environmentally compatible and economically feasible to reduce pest populations. Chapter 5 by K. O. Story on "The role on inspection, diagnosis, pest population monitoring and consultation" and chapter 6 by E. F. Wood on "Other non-chemical components essential to pest management" are particularly useful. Van Nostrand/Rheinold, N. York. Approx. 250pp.

BENNETT, G. W., E. RUNSTROM and J. BERTHOLF. 1984. Examining the where, why and how of cockroach control. Pest Control 52(6): 42, 43, 46, 48.

Reviews the latest research of Purdue University including data on the importance of taking the behavior of cockroaches into account in IPM programs. Pesticides found to be highly effective include Raid Roach Bait, Knox Out spray, Cypermethrin wettable powder spray and Ficam Dust. The insect growth regulator hydroprene works best when combined with conventional insecticides.

BLETCHLY, J. D. 1967. Insect and marine borer damage to timber and woodwork. Ministry of Tech.: For. Prod. Res., London: 88pp.

Preventive and remedial measures, chemical and physical treatment. Taxonomy, biology, life cycles. Inspection techniques, diagnostic damage. Wood preservation standards.

BURKHOLDER, W. E. 1977. Manipulation of insect pests of stored products. In: Chemical control of insect behavior: theory and application by H. H. Shorey, et al., Editors. John Wiley and Sons, Inc.: 345-51.

An integrated approach to control may include the use of inert gases, radiation, pathogens, growth regulators, pheromones, sanitation, inspection, good packaging and storage facilities, and pesticides.

CLAMP, C., Jr. 1983. Integrated protection against structural wood-infesting pests. Part four. Pest Management 2(4): 20-21.

A technique for protecting hardwood molding against lyctid beetle infestation is reviewed.

COCHRAN, D. G. 1984. Insecticide resistance in cockroaches - is it at a crossroad? Pest Management 3(8): 26-31.

In the light of some resistant strains of cockroaches in the field, including some multiresistant strains, an approach is proposed for dealing with problem strains. This might involve sequential use of a synthetic pyrethroid, followed by boric acid, followed by an amidinohydrazone bait, followed by an OP insecticide. The details could vary but the concept relies on the short term use of insecticides with totally different modes of action.

CYMOREK, S. 1970. Imported and native powder-post beetles (Coleoptera: Bostrychidae, Lyctidae): survey of their habits, occurrence, importations, economic significance and control. Z. Angew. Entomol., Hamburg 66(2): 206-24.

DAVIS, R. 1984. Letter to Dr. Mello of S.I. dated June 21st, 1984.

Relates to his recent visit to Silver Hill and makes recommendations re. use of phosphine, Vikane, DDVP (for herbarium specimens) and lindane. Encloses list of references relating to conventional fumigants, heat treatments, atmospheric gases, and irradiation.

EBELING, W. 1975. Urban entomology. Univ. of California. 695pp.

Good general treatment of biology and control of urban pests, including cockroaches and stored product pests. Particularly strong references to use of boric acid for cockroach control based on earlier research by Ebeling.

GALLO, F. (In press). Biological factors in the deterioration of library and archive materials. ICCROM, Rome.

Review of threats from insects and micro-organisms, recognition of damage, and environmental conditions preventing infestations and infections.

EDWARDS, S. R., B. M. BELL and M. E. KING. 1980. Pest control in museums: a status report. Association of Systematics Collections.

HOMER, C. 1967. Bug of the month - Drugstore beetle Stegobium paniceum. PCO News 27(9): 31.

General description, life cycle, importance and control.

HOMER, C. 1969. Bug of the month - Cigarette beetle Lasioderma serricorne. PCO News 29(3): 31.

KATZ, H. 1979. Integrated pest management then and now. Pest Control 47(11): 16-18, 36, 38, 40, 81.

An article which discusses integrated pest management as a technique for the PCO's to use in the structural pest control industry. Examples of modifications to building structures, habitats, environments and proper sanitation are provided to emphasize the fact that no longer can indiscriminate use of potentially hazardous pesticides be the panacea. It explains how the successful PCO will have to treat both the symptoms and the cause of the pest problem.

KATZ, H. L. 1982. Fabric pests are back! IPM Pract. 4(3): 3-5.

An article which provides a thorough discussion of the ways one can control the most common household fabric pests in the USA. Included are the biology and identification of the clothes moth, the common carpet beetle and the black carpet beetle as well as the various ways control measures can be utilized.

LINDSAY, I. 1969. The protection of military stores and personnel from insect pests. 9th Commonwlth. Defence Conf. on clothing and general stores, Kenya: 11pp.

General discussion of pests and control measures.

MALLIS, A., et al. 1982. Handbook of Pest Control, 6th Edition. Editor K. O. Story. Franzak & Foster, Co., Cleveland. 1101pp.

The leading textbook on pest control in and around buildings. The inputs of Mallis and 16 other contributing authors cover the behavior, life history and control of vertebrate and invertebrate pests, including pests commonly found in museums. Substantial data on non-chemical and chemical control methods, including a useful chapter on pest control equipment. Good glossaries of technical terms and trade names of pesticides. Profusely illustrated.

MOORE, H. B. 1979. Wood-inhabiting beetles in houses: their identification, biology, prevention and control. USDA Forest Service and HUD Office of Policy Development & Research. 133pp.

MORELAND, D. 1981. Pantry pests. Pest Control Technol. 9(2): 22-26.

Briefly reviews biology of 12 stored product pests, including cigarette beetle, drugstore beetle, carpet beetle and golden spider beetle. Control recommendations include use of heat and cold as well as improved sanitation.

MORELAND, D. 1984. A layman's guide to German cockroach research. Pest Control Technol. 12(3): 43, 44, 46.

Summary of recent research work conducted at North Carolina State University, Purdue University, U. Cal. at Riverside, Virginia Polytechnic Institute and State University, University of Maryland and University of Nebraska. Many researchers endorsed the use of sticky traps for monitoring cockroach populations.

OSMUN, J. V. 1971. Household insects. In: Fundamentals of applied entomology. Second edition by R. E. Pfadt, Editor. MacMillan Co., New York: 523-49.

Some detailed information on the biology and control of German, Oriental, American, and brownbanded cockroaches; clothes moths; carpenter, Pharaoh, little black and fire ants; and termites are given.

SPENCER, G. J. 1963. Control of pests in insect and herbarium cabinets. Proc. Ent. Soc. Brit. Col. 60: 23-26.

ST. GEORGE, R. A., et al. Powder-post beetles in buildings. What to do about them. USDA leaflet No. 358 (Rev.): 8pp.

Life cycle, habit, damage and control procedures.

STORY, K. O. 1984. Cockroach control. Video film focusing on the biology and control of German cockroaches. International Educational Enterprises, Cleveland. 30 minutes.

Superb shots depicting cockroach behavior and guidance on how to conduct an integrated pest eradication program based on chemical and non-chemical approaches.

STORY, K. O. 1984. Insect Pest Management. Published by the American Cemetery Association, Falls Church, Va.: 139pp.

Comprehensive coverage of the biological background and recommendations for prevention or control of insects in mausoleums using a combination of chemical and non-chemical approaches. Deals primarily with phorid flies and dermestid beetles. 24 references cited.

STORY, K. O. 1985. Pest control in high-tech areas. Pest Control Technol. 13(7): 42-44, 46, 47.

Outlines integrated pest management programs for sensitive environments, including animal research laboratories, control rooms and computer rooms. Detailed case history of an IPM program for cockroach control in animal rooms of a pharmaceutical facility, focusing on minimizing adverse effects on the animals and research program. The involvement of on-site staff in discouraging pests is stressed.

TODARO, W. 1984. Public housing - the pest control industry's ultimate challenge. Pest Control Technol. 12(8): 61, 62, 64, 76.

Report on an IPM program against cockroaches conducted by the Allegheny County Health Dept. in public housing in Pittsburgh. Combinations of good sanitation and use of insecticide sprays and dusts achieved good control. Results were poor where sanitation was poor or where insecticide dusts were not used.

TRUMAN, L. C., G. W. BENNETT and W. L. BUTTS. 1976. Scientific guide to pest control operations. Third edition. Harvest Publ. Co., Cleveland: 276 pp.

The book includes chapters on principles of pest control and introductory entomology, insect development and identification, pesticides, safety, equipment, cockroaches, termites, wood pests, hymenopterous pests, stored product pests, parasites, fabric insects, flies and mosquitoes, rats and mice, birds and other vertebrate pests, sanitation, management and public health pest control.

VON FRISCH, K. 1964. Ten little housemates. MacMillan Co., New York: 146pp.

Popular information on morphology bionomics and control of 10 groups of arthropods found in houses; includes clothes moths, silverfish and spiders.

WALTER, V. 1982. Source of a warehouse infestation. Pest Control 50(9): 62, 63.

The article emphasizes the importance of inspecting the infested material, the building and shipping vehicles. Clues for determining the origin and age of an infestation are presented.

WARE, G. W. 1980. Complete guide to pest control with and without chemicals. Thomson Publ., Fresno: 290pp.

This book is a catalog of pests and pesticides, presented in layman's terms, covering most facets of pest control, both chemical and non-chemical. Brief descriptions of the most common insect pests affecting plants and animals, the equipment utilized in pest control, safe handling of pesticides and a review of the major regulations concerning pest management is included.

WEST, A. S., et al. 1981. Canadian Forces Manual on Pest Control. Fourth edition. Dep. Natl. Def., Ottawa: 338pp.

A detailed pest control manual prepared specifically for use by the Canadian Armed Forces. Included in this text are the ways to detect infestations of insects and other pests, follow-up surveys, selection and application of control methods with emphasis on integrated pest management where applicable.

WESTRATE, D. F. 1984. Warning: your collection may be bugged. American Philatelist 98(9): 929-932.

The author summarizes pest problems of stamp collections, including beetles, rodents, fungi, booklice, silverfish and cockroaches. Methods of preventing problems are cited with an emphasis on reducing moisture and removing pest harborages and food sources. Excellent illustrations (8) of pest damage.

WOOD, G. and J. NIXON. 1978. Integrated pest management in multifamily housing. Pest Control 51(9): 23, 26, 27.

The article focuses on cockroach control and discusses the following IPM steps: training building management, inspection, record-keeping, identifying pests, identifying maintenance problems, determining pest foci, training building occupants, applying pesticides, following-up, ongoing monitoring.

ZUNGOLI, P. A. 1983. German cockroach control: a game of wits. Pest Control Technol. 11(8): 56-58.

Emphasizes the need to think about the various components of a roach control program, including the causes of infestation and the choice of materials and methods. References several research papers which have contributed to greater knowledge of cockroach biology, behavior and control methods with conventional pesticides.

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INDEX OF CHEMICAL NAMES

This index lists common names of chemicals used against pests, together with examples of registered trade names.

COMMON NAME:	*REGISTERED TRADE NAME(S):*
Chlordane	BELT, OCTACHLOR, ORTHO-KLOR, VELSICOL 1068.
Chlordecone	KEPONE
Chlorfenethol	DIMITE, MITRAN, QUIKRON.
Chlorfenson	CROTRAR, OVEX, OVOTRAN, SAPPIRON.
Chlorophacinone	CALD, DRAT, LIPHADIONE, MICROZUL, QUICK, RAMICIDE, ROZOL, TOPITOX.
Chloropicrin	ACQUINITE, LARVACIDE, PIC-CHLOR, PICFUME.
*3-chloro-p-toluidine hydrochloride	STARLICIDE
Chlorpyrifos	DURSBAN, KILLMASTER, LORSBAN.
Coumachlor	RATILAN, TOMORIN.
Coumafuryl	FUMARIN, FUMASOL, LURAT, RAT-A-WAY.
Cypermethrin	DEMON
DDT	GESAROL, NEOCID.
*20,25 diazacholesterol dihydrochloride	ORNITROL
Diazinon	BASUDIN, NUCIDOL, SAROLEX, SPECTRACIDE.
Dichlorvos or DDVP	DEDEVAP, NO-PEST, NUVAN, VAPONA, VAPONITE.
Dicofol	KELTHANE
Dieldrin	OCTALOX
Diflubenzuron	DIMILIN, TH 6040.
Dimethoate	CYGON, DE-FEND, DIMETATE, PERFEKTHION, ROXION.
Dimetilan	SNIP
Dioxacarb	ELOCRON, FAMID.
Dioxathion	DELNAV, DELTIC.
Diphacinone	DIPHACIN, PID, PROMAR, RAMIK.
Endrin	ENDREX, HEXADRIN, MENDRIN, RID-A-BIRD.

COMMON NAME:	*REGISTERED TRADE NAME(S):*
Ethylene dibromide or EDB	BROMOFUME, CELMIDE, DOWFUME, FUMOGAS, NEPHIS.
Fenitrothion	CYFEN, FOLITHION, SUMITHION, VERTHION.
Fenthion	BAYCID, BAYTEX, ENTEX, LEBAYCID, RID-A-BIRD.
Fenvalerate	PYRID
Fluoracetamide	FLUORAKIL, FUSSOL, YANOCK, COMPOUND 1081 (code).
Heptachlor	DRINOX, HEPTAMUL.
Hydrogen cyanide, HCN or hydrocyanic acid	CYCLON
Hydroprene	GENCOR
Iodofenphos	ALFACRON, ELOCRIL, NUVANOL N.
Isobornyl thiocyanoacetate	THANITE
Isovaleryl indandione	INCCO, ISOVAL, PMP, VALONE.
Lindane, gamma BHC or gamma HCH	GAMMEXANE, KWELL.
Malathion	CYTHION, KARBOPHOS, MALATHIOZOL, SUMITOL.
Metaldehyde	META, HELARION.
Methiocarb	DRAZA, MESUROL.
Methoprene	ALTOSID, PHARORID, PRECOR.
Methoxychlor	MARLATE
Methyl bromide	BROM-O-GAS, BROZONE, METH-O-GAS, TERR-O-GAS.
Mirex	GC 1283 (code).
Naled	DIBROM
Norbormide	SHOXIN, RATICATE.
Paradichlorobenzene or PDB	PARACIDE, PARA-DI, PARADOW.
Parathion	BLADAN, FOLIDOL, NIRAN, THIOPHOS.

COMMON NAME:	*REGISTERED TRADE NAME(S):*
Pentachlorophenol or PCP	DOWICIDE, PENTA, SANTOBRITE, SANTOPHEN.
Permethrin	ECTIBAN, NRDC 143 (code), PERIGEN, TORPEDO, VICKERS SMA-V.
Pindone	CHEMRAT, DUOCIDE, PIVAL, PIVALDIONE, TRI-BAN.
Piperonyl butoxide	BUTACIDE
Pirimiphos-methyl	ACTELLIC, ACTELLIFOG, BLAX.
Propetamphos	SAFROTIN
Propoxur	BAYGON, BLATTANEX, SUNCIDE, UNDENE.
Red squill	DETHDIET, RODENE, RODINE, SILMURIN, TOPZOL.
Resmethrin	CHRYSON, CROSS FIRE, SYNTHRIN.
Ronnel, or fenchlorvos	KORLAN, NANKOR, TROLENE.
Rotenone	DERRIS
Silica aerogel	DRIAONE, DRI-DIE, DRIONE, SILIKIL.
Sodium aluminum silicofluoride	LARVEX
Sodium fluoride	FLOROCID
Sodium fluoracetate	COMPOUND 1080 (code).
Strychnine	KWIK-KIL, RODEX.
Sulfuryl fluoride	VIKANE
Temephos	ABATE, ABATHION, BIOTHION, NIMITEX, SWEBATE.
TEPP	NIFOS, VAPOTONE.
Tetramethrin	NEO-PYNAMIN
Toxaphene	ATTAC
Trichlorfon	ANTHON, DIPTEREX, DYLOX, NEGUVON, TUGON.
Vitamin D_3, or cholecalciferol	QUINTOX

COMMON NAME:	*REGISTERED TRADE NAME(S):*
Warfarin	COUMAFENE, DETHMOR, DUOCIDE, WARFARICIDE.
Zinc phosphide	RIDALL-Z, RUMETAN, ZP.

* No common name for these chemicals.

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GLOSSARY OF TECHNICAL TERMS

This glossary provides definitions of some entomological and other technical terms used in this book and in the cited publications. Some of these terms have additional or different meanings when used elsewhere.

ABDOMEN — the posterior of the three main body divisions.

ABSORPTION — the process of one substance (usually gas or liquid) being taken into another substance (usually liquid or solid).

ACUTE ORAL LD_{50} — in toxicological studies the dose required to kill 50% of the test animals when given as a single dose by mouth. The dose is normally expressed as the weight of chemical per unit weight of animal (e.g. mg/kg).

ADSORPTION — the adhesion of substances in an extremely thin layer to the surfaces of solids or liquids with which they are in contact.

AESTIVATION — dormancy during a warm or dry season.

ALIPHATIC — belonging to a group of organic compounds having an open-chain structure and consisting of the paraffin, olefin and acetylene hydrocarbons and their derivatives.

ALATE — winged.

AMETABOLOUS — without metamorphosis (e.g. silverfish).

ANAL — pertaining to the last abdominal segment (which bears the anus); (also the posterior basal part of the wing of insects).

ANTENNAL CLUB — the enlarged distal segments of a clubbed antenna (e.g. drugstore beetle).

ANTERIOR — front; in front of.

ANUS — the posterior opening of the alimentary tract.

APICAL — at the end, tip, or outermost part.

BASAL	at the base; near the point of attachment (of an appendage).
BASAL CELL	a cell near the base of an insect's wing, bordered at least in part by the unbranched portions of the longitudinal veins.
BROOD	the individuals arising from one mother; individuals that hatch at about the same time and normally mature at about the same time.
CANNIBALISTIC	feeding on other individuals of the same species.
CARNIVOROUS	feeding on the flesh of other animals.
CARRIER	the liquid or solid material added as a diluent to a pesticide to facilitate its application.
CATERPILLAR	a larva with a cylindrical body, a well developed head and with both thoracic legs and abdominal prolegs (e.g. butterfly, moth, sawfly).
CELL	a unit mass of protoplasm, surrounded by a cell membrane and containing one or more nuclei or nuclear material; a space in the wing membrane partly or completely surrounded by veins.
CEPHALOTHORAX	a body region consisting of head and thoracic segments (Crustacae and Arachnida).
CERCUS	(pl. CERCI) one of a pair of appendages at the end of the abdomen.
CHELATE	pincerlike, having two opposable claws.
CHITIN	a nitrogenous polysaccharide occurring in the cuticle of arthropods.
CHRONIC TOXICITY	relating to long-term toxic effects, such as carcinogenicity, mutagenicity, teratogenicity and neurotoxicity.
CHRYSALIS	(pl. CHRYSALIDS or CHRYSALIDES) the pupa of a butterfly.
CLASS	a subdivision of a phylum or subphylum, containing a group of related orders.
CLEFT	split or forked.
COCOON	a silken case inside which the pupa is formed.
COMMENSALISM	a living together of two or more species, none of which is injured thereby, and at least one of which is benefited.

COMPOUND EYE	an eye composed of many individual elements or ommatidia, each of which is represented externally by a facet; the external surface of such an eye consists of circular facets that are very close together, or of facets that are in contact and more or less hexagonal in shape.
CONTACT INSECTICIDE	an insecticide which works when the insect is directly exposed to airborne particles, droplets or vapor.
COXA	(pl. COXAE) the basal segment of the leg of an arthropod.
CROSS VEIN	a vein connecting adjacent longitudinal veins of an insect wing.
CTENIDIUM	(pl. CTENIDIA) a row of stout bristles like the teeth of a comb (e.g. fleas).
CUTICLE	the noncellular outer layer of the body wall of an arthropod.
DESSICANT	a compound which promotes loss of moisture.
DIAPAUSE	a period of arrested development.
DISTAL	near or toward the free end of an appendage; that part of a segment or appendage farthest from the body.
DISTILLATE	a liquid product condensed from vapor during distillation.
DIURNAL	active during the daytime.
DORMANCY	a state of quiescence or inactivity.
DORSAL	top or uppermost; relating to the back or upper side.
ECDYSIS	molting; the process of shedding the exoskeleton.
ECTOPARASITE	a parasite that lives on the outside of its host.
ELBOWED ANTENNA	an antenna with the first segment elongated and the remaining segments coming off the first segment at an angle (e.g. ants).
ELYTRON	(pl. ELYTRA) a thickened, leathery, or horny front wing (e.g. Coleoptera, Dermaptera and some Homoptera).
EMERGENCE	the act of the adult insect leaving the pupal case or the last nymphal skin.

EMULSIFIABLE CONCENTRATE see "Formulation".

EMULSIFIER a surface-active chemical which reduces interfacial tension and which can be used to facilitate formation of an emulsion of one liquid in another.

EMULSION a mixture in which very small droplets of one liquid are suspended in another liquid, e.g. oil in water. When the emulsion consists of droplets of water in oil it is known as an "invert" or "mayonnaise" emulsion.

ENDOCUTICLE the innermost layer of the cuticle.

EPICUTICLE the very thin, nonchitinous, external layer of the cuticle.

EPIPHARYNX a mouth-part structure on the inner surface of the labrum or clypeus; in chewing insects a median lobe on the posterior (ventral) surface of the labrum or clypeus.

EXOCUTICLE the layer of the cuticle just outside the endocuticle, between the endocuticle and the epicuticle.

EXOSKELETON a skeleton or supporting structure on the outside of the body.

EYE, SIMPLE see "Ocellus".

FAMILY a subdivision of an order, suborder, or superfamily, and containing a group of related genera, tribes, or subfamilies. Family names end in *-idae*.

FEMUR (pl. FEMORA) the third leg segment, located between the trochanter and the tibia of arthropods.

FERAL wild, including having escaped from domestication and become wild (e.g. feral cats, feral pigeons).

FORMULATION the process by which pesticides are prepared for practical use or a preparation containing a pesticide in a form suitable for practical use, e.g. Emulsifiable concentrate - a type of formulation for spray application consisting of a concentrated solution of a pesticide and an emulsifier in an organic solvent, which will form an emulsion when added to water and agitated. Granule - a type of formulation for dry application consisting of granules which serve as a carrier for the pesticide. Wettable powder - a type of formulation for spray application in which a pesticide is mixed with an inert carrier, the product finely ground and a surface-active agent added so that it will form a suspension when agitated with water.

FOREWING	the anterior or front pair of wings.
FRASS	plant fragments made by a wood-boring insect, usually mixed with excrement.
FUNICULUS	(or FUNICLE) the antennal segments between the scape and the club.
GASTER	the rounded part of the abdomen posterior to the nodelike segment (ants).
GENERATION	from any given stage in the life cycle to the same stage in the offspring.
GENUS	(pl. GENERA) a group of closely related species; the first name in a binomial or trinomial scientific name. Names of genera are Latinized, capitalized, and when printed are italicized.
GRANULE	see "Formulation".
GREGARIOUS	living in groups.
GRUB	a thick-bodied larva with a well-developed head and thoracic legs, without abdominal prolegs, and usually sluggish but often wriggling when disturbed.
HALTER	(pl. HALTERES) a small knobbed structure on each side of the metathorax representing the hind wings (Diptera).
HEAD	the anterior body region, which bears the eyes, antennae, and mouth parts.
HERBIVOROUS	feeding on plants.
HIBERNATION	dormancy during the winter.
HOST	the organism in or on which a parasite (or parasitoid) lives; the plant on which an insect feeds.
HYPOPHARYNX	a median mouth-part structure anterior to the labium; the ducts from the salivary glands are usually associated with the hypopharynx, and in some sucking insects the hypopharynx is the mouth-part structure containing the salivary channel.
INSTAR	the stage of an insect between successive molts, the first instar being the stage between hatching and the first molt.
INSTINCTIVE BEHAVIOR	unlearned, stereotyped behavior in which the nerve pathways involved are hereditary.
INTEGUMENT	the outer covering of the body.

JOINT	an articulation of two successive segments or parts.
LABIAL	of or pertaining to the labium.
LABIUM	one of the arthropod mouth-part structures; the lower lip.
LABRUM-EPIPHARYNX	a mouth-part representing the labrum and epipharynx.
LARVA	(pl. LARVAE) the immature stages, between the egg and pupa, of an insect having complete metamorphosis or the six-legged first instar of Acarina. Larvae are distinctly different from the adult.
LARVIFORM	shaped like a larva.
MAGGOT	a legless larva without a well-developed head capsule (e.g. Diptera).
MANDIBLE	jaw; one of the anterior pair of the paired mouth-part structures.
MARGINAL CELL	a cell in the distal part of the insect wing.
MAXILLA	(pl. MAXILLAE) one of the paired mouth-part structures immediately posterior to the mandibles of arthropods.
MESONOTUM	the dorsal sclerite of the mesothorax.
MESOTHORAX	the middle or second segment of the thorax.
METAMORPHOSIS	change in form during development.
METATHORAX	the third or posterior segment of the thorax.
MOLT	a process of shedding the exoskeleton. Also known as ecdysis.
MORPHOLOGY	the science of form or structure.
NOCTURNAL	active at night (e.g. cockroaches).
NODE	a knoblike swelling.
NOTUM	(pl. NOTA) the dorsal surface of a body segment (usually used when speaking of the thoracic segments).
NYMPH	an immature stage (following hatching) of an insect that does not have a pupal stage; the immature stages of Acarina that have eight legs.
OCELLUS	(pl. OCELLI) a simple eye of an insect or other arthropod.

OLEFIN	an unsaturated open-chain hydrocarbon containing at least one double bond.
OMNIVOROUS	feeding on a wide variety of substances of both animal and vegetable origin.
ONCOGENIC	inducing tumors.
OOTHECA	(pl. OOTHECAE) the covering or case of an egg mass (e.g. cockroaches).
ORDER	a subdivision of a class or subclass, containing a group of related families.
OVIPOSIT	to lay or deposit eggs.
OVIPOSITOR	the egg-laying apparatus; the external genitalia of the female.
PALP	a segmented process borne by the maxillae or labium.
PATHOGEN	or PATHOGENIC ORGANISM — an organism which causes a disease in the animal receiving it.
PARASITE	an animal that lives in or on the body of another living animal (its host), at least during a part of its life cycle.
PARTHENOGENESIS	reproducing by eggs that develop without being fertilized.
PECTEN	a comblike or rakelike structure.
PECTINES	Comblike organs of touch (e.g. scorpions).
PEDICEL	the second segment of the antenna; the stem of the abdomen, between the thorax and the gaster (ants), or between the head-thorax and the abdomen (spiders).
PEDIPALPS	the second pair of appendages of an arachnid.
PENULTIMATE	next to the last.
PH (pH)	a measure of the acidity or alkalinity of a medium. A pH value of 7.0 indicates neutral; lower values indicate acid and higher values indicate alkaline.
PHEROMONE	a chemical substance produced by an animal which acts as a stimulus to other individuals of the same species for one or more behavioral responses (e.g. aggregation pheromone and sex pheromone).
PHYTOTOXIC	toxic to at least some plants.

PILOSE	covered with hair. PILOSITY — hairiness.
POLYMORPHIC	having many different forms or sizes (e.g. worker ants of some species).
POSTNOTUM	(pl. POSTNOTA) a notal plate behind the scutellum, often present in wing-bearing segments.
PREAPICAL	situated just before the apex (e.g. preapical tibial bristle of flies).
PHYLUM	(pl. PHYLA) one of the dozen or so major divisions of the animal kingdom.
PREDATOR	an animal that attacks and feeds on other animals (its prey), usually animals smaller or less powerful than itself.
PREPUPA	a quiescent stage between the larval period and the pupal period.
PROBOSCIS	extended beaklike mouthparts.
PRONOTUM	the dorsal sclerite of the prothorax.
PROTHORAX	the anterior of the three thoracic segments.
PTILINUM	a temporary bladderlike structure that can be inflated and thrust out through the frontal suture, just above the bases of the antennae, at the time of emergence from the puparium (Diptera).
PUBESCENT	covered in fine, short hairs.
PUPA	(pl. PUPAE) the stage between the larva and the adult in insects with complete metamorphosis, a nonfeeding and usually an immobile stage.
PUPARIUM	(pl. PUPARIA) a case formed by the hardening of the next to the last larval skin, in which the pupa is formed (Diptera).
PUPATE	to transform to a pupa.
RAD	a unit of absorbed dose of ionizing radiation.
RESIDUAL INSECTICIDE	an insecticide which remains capable of killing insects which contact treated surfaces long after the application.
RESISTANCE	the ability of pests to avoid or mitigate the toxic effects of pesticides. The basis of resistance may be physical, physiological or behavioral.

ROSTRUM	beak or snout.
SCAPE	the basal segment of the antenna.
SCAVENGER	an animal that feeds on dead plants or animals, on decaying materials, or on animal wastes.
SCENT GLAND	a gland producing an odorous substance.
SCIENTIFIC NAME	a Latinized name, internationally recognized, of a species or sub-species. The scientific name of a species consists of the generic and specific name and the name of the describer of the species, and that of a subspecies consists of generic, specific, and subspecific names and the name of the describer of the subspecies. Scientific names (excluding authors' names) are always printed in italics.
SCLERITE	a hardened body wall plate bounded by sutures or membranous areas.
SCLEROTIZED	hardened.
SCUTELLUM	a sclerite of a thoracic notum.
SCUTUM	the middle division of a thoracic notum, just anterior to the scutellum. Also the plate on the back of ticks.
SEGMENT	a subdivision of the body or of an appendage, between joints or articulations.
SERRATE	toothed along the edge like a saw; serrate antenna; serrate bristles.
SETA	(pl. SETAE) a bristle.
SETACEOUS	bristlelike, e.g. setaceous antenna.
SETATE	provided with bristles.
SIMPLE	unmodified, not complicated; not forked, toothed, branched or divided.
SPECIES	a group of individuals or populations that are similar in structure and physiology and are capable of interbreeding and producing fertile offspring, and which are different in structure and/or physiology from other such groups and normally do not interbreed with them.
SPINNERET	a structure with which silk is spun, usually fingerlike in shape.

SPIRACLE	an external opening of the tracheal system; a breathing pore.
SPIRACULAR BRISTLE	a bristle very close to a spiracle (Diptera).
SPUR	a movable spine; when on a leg segment usually located at the apex of the segment.
STERNITE	a subdivision of a sternum.
STERNUM	(pl. STERNA) a sclerite on the ventral side of an arthropod's body; the ventral sclerite of an abdominal segment.
STIGMA	(pl. STIGMATA) a thickening of an insect's wing membrane along the costal border of the wing near the apex. Also respiratory opening in mites and ticks.
STYLUS	(pl. STYLI) a short, slender, fingerlike process.
SUBCLASS	a major subdivision of a class, containing a group of related orders.
SUBLIMATION	the process of causing a substance to pass from a solid state directly to the vapor state (by heating) and then condensing again to solid form (e.g. in production of flake naphthalene).
SUBSPECIES	a subdivision of a species, usually a geographic race. The different subspecies of a species are ordinarily not sharply differentiated and intergrade with one another and are capable of interbreeding.
SURFACE-ACTIVE AGENTS	or SURFACTANTS — substances which, when added to a liquid, affect the physical properties of the liquid surface (e.g. for the formulation of emulsifiable concentrates and wettable powders and for increasing the wetting properties of sprays).
SUSPENSION	particles or microcapsules of pesticide suspended in liquid.
SYNERGISM	the combined effect of two or more pesticides mixed together leading to a greater pesticidal effect than would be predicted from the behavior of each component when applied singly.
SYNERGIST	a chemical that enhances the effectiveness of an active ingredient.

TARSUS	(pl. TARSI) that leg segment behond the tibia in arthropods, consisting of one or more segments or subdivisions.
TAXIS	(pl. TAXES) a directed response involving the movement of an animal toward or away from a stimulus.
TAXONOMY	the science of classification into categories of varying rank, based on similarities and differences, and the describing and naming of these categories.
TERPENES	any of various hydrocarbons $(C_5H_8)_n$ found in essential oils and resins (esp. from conifers) and used especially as solvents.
THIGMOTAXIS	a movement in which surface contact (esp. with a solid or a rigid object) is the directive factor.
TIBIA	(pl. TIBIAE) the fourth segment of an arthropod's leg, between the femur and the tarsus.
TRACHEA	a tube of the respiratory system opening to the outside at a spiracle and terminating internally in tracheoles.
TROPHALLAXIS	Food exchange of mutual benefit (esp. in social insects).
TUBERCLE	a small knoblike or rounded protuberance.
VECTOR	an animal capable of transmitting a pathogen from one organism to another.
VENTER	the ventral side.
VITELLINE MEMBRANE	the cell wall of the insect egg; a thin membrane lying beneath the chorion.
WETTABLE POWDER	see "Formulation".

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APPENDIX

CRITERIA FOR CHOOSING PESTICIDES

The following criteria or properties are generally desirable when choosing a pesticide for use in museum buildings or on collection items.

1. Pesticide should be federally registered for this or similar uses.
2. Pesticide should be state registered for this or similar uses.
3. Pesticide should be labeled for the specific target pest or related pests.
4. Pesticide should have a record of being effective against the target pest at labeled dose rates.
5. Pesticide should be labeled for the site of use (e.g. indoors, outdoors, food areas, etc.).
6. Pesticide (excluding fumigants) should have low volatility to minimize vapor contamination of non-target areas.
7. Pesticide should have low odor to minimize disturbance of museum staff and visitors.
8. Pesticide should be non-irritant to the skin, eyes and lungs.
9. Pesticide should have a good overall record of safety to users and occupants of treated buildings.
10. Pesticide should be non-corrosive, non-staining and without a history of damaging the surfaces targeted for treatment.
11. Pesticide should have a record of safe use in the museum environment.
12. Pesticide should be backed by a knowledgeable, responsible and communicative manufacturer.

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