injected through it under pressure.

Any excess chemical which backs up around the rod is held next to the foundation in the trench. The grouting rod injections may need to be closer together in hard-packed clay soils than in light, sandy soils. When the rodding is completed, refill the trench, saturating the soil with chemical. Some label directions indicate that a thin layer of untreated soil should be placed on top of the treated soil.

- Apply 4 gallons (15 liters) per 10 linear feet (3 cm) along and against the inside and outside foundation walls of porches and other raised appurtenances, using shallow trenches to retain the chemical against the foundations. The trenches should be refilled and treated as indicated above.
- Apply 1 gallon (4 liters) per 10 square feet (1 sq m) of soil surface as an overall treatment, only where the attached concrete platforms and porches will be on fill or ground. Do not apply an overall treatment in crawl spaces.
- Apply 2 gallons (7.5 liters) of chemical per 10 linear feet (3 m) of wall at or near the footing into voids in masonry blocks or foundations. If voids have been capped, drill holes into them near the footing and inject the chemical to form a continuous barrier.

3. Basement houses: Soil under the entire area of the basement floor, under adjacent entrance, porch, garage and carport slabs and around the perimeter of the basement wall should be treated (Fig. 2-12).
    - Soil under the basement floor and other slabs is treated under slab-on-ground construction (Part 1 above).
    - The soil outside of the basement wall is treated as in crawl space construction (Part 2 above).
    - Where there are voids in masonry foundations, treat as in Parts 1 and 2, above. Keep in mind that the insecticide is applied in the foundation wall at or near the footing, not from the top of a high basement wall.
4. Multi-level houses are treated according to the individual component parts, using the specifications which apply to each. They are very difficult to treat properly if infested later.

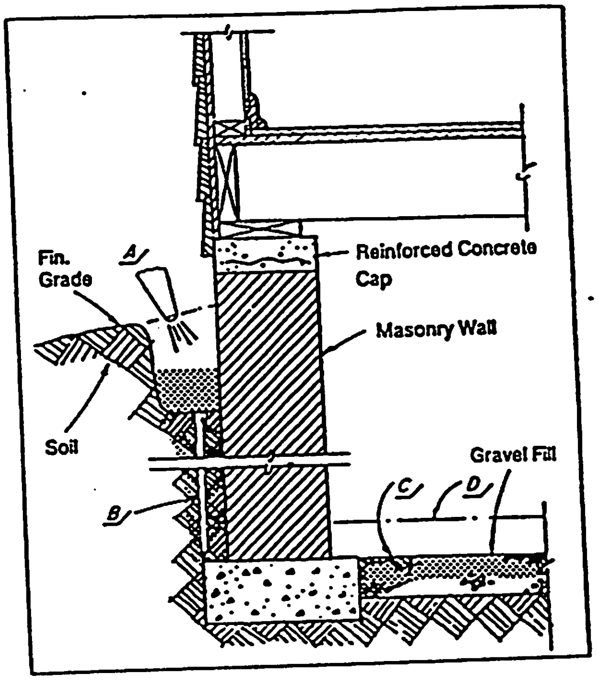


FIGURE 2-12. Application of chemical to the soil and around a house with a full basement. A. Soil treatment along the outside of the foundation; B. Pipe and rod hole from the bottom of trench to the top of the footing to aid distribution of chemical. C. Treatment of fill or soil beneath a concrete floor in basement. D. Position of concrete slab after chemical has been applied. Adapted from USDA.

Soil type and the amount of moisture present may have an effect on the acceptance of liquids at the rates recommended. When a soil will not accept the correct volume of insecticide formulation, some labels provide for adjusting the concentration of toxicant upward and applying a lower volume. For example, five gallons of 0.5 percent cypermethrin is the equivalent of 10 gallons of 0.25 percent cypermethrin in terms of actual insecticide available. Proper distribution of the lesser volume might be more difficult, and distribution is the key to the success of such a manipulation. At the present time, label directions must be followed, and most do not allow adjustments of this type. It is hoped that such leeway might eventually become available to knowledgeable applicators.

It is important to be aware of several general precautions and other considerations. The Environmental Protection Agency requires that treated soil to be covered by a concrete slab be protected with a polyethylene sheet or other waterproofed material, unless the concrete is to be poured on the day of the treatment. This is to avoid washing away of insecticide by rain.

It is equally important to protect the treated soil from any disturbance which might break the continuity of the insecticide barrier. The layer of treated soil provided by the overall treatment of fill under slabs is probably less than 2 inches (5 cm) thick, and most of the chemical is in the top 3/4 inch (2 cm) of soil (Beal and Carter, 1968). Something as simple as a board being dragged across a treated fill can create a line of untreated soil turned from underneath by the furrow. That is why it is essential that final treatment on the outside of foundation walls be done after all grading and other soil disturbance has been completed.

If large stones or chunks of concrete or mortar, as well as wood scraps are incorporated in dirt fill adjacent to foundation walls, problems in proper soil treating result. When the chemical is applied in a trench, or if rods are used to inject the toxicant to the footing, obstructions to downward movement create "shadows" of untreated soil below the obstruction (Fig. 2-13). Lateral movement of chemicals in many soils is so restricted that there might not be overlap between holes, even with extra treating on each side of the obstruction.

Any wood debris incorporated in the back-

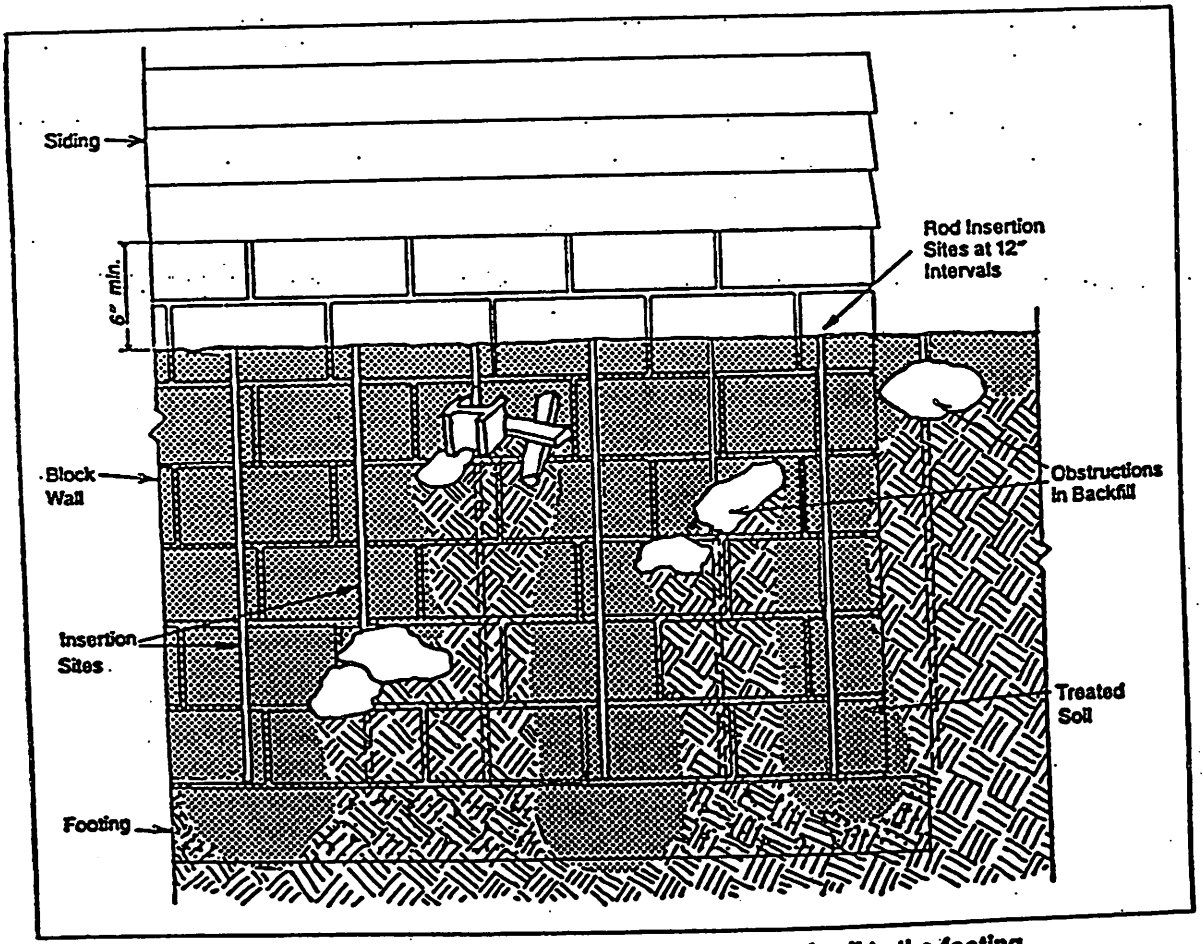


FIGURE 2-13. Obstructions in backfill prevent complete treatment of soil to the footing.

fill serves as food for termites and also might well extend from the face of the wall into untreated soil. This will allow termites outside of the chemical barrier to consume the wood and increase their population. Ultimately, they will penetrate the length of the wood debris and be in contact with the foundation. Any tiny crack or crevice greater than 1/32 inch (0.8 mm) will allow entry into the wall. The higher population of termites increases their persistence and thus pressure against chemical and physical barriers.

Treatments should not be made when soil is excessively wet or immediately after heavy rains in order to obtain good penetration into the soil and to avoid possible run-off of the chemical. Best penetration results when the soil is damp but not excessively wet or dry. Once the insecticide emulsion which has been applied to the soil has "broken" (the water has left the globules of insecticide oil solution), it is then stable in the soil. The insecticide adheres so tightly to the soil particles that the soil essentially must be moved in order for the chemical to move. The recommended insecticides are almost insoluble in water, so leaching is not a problem.

One step in the treatment that is often misunderstood is that of applying the chemical to the voids in foundations. The recommendations indicate that it should be applied at or near the footing. The purpose of this treatment is not to generally flood the surfaces of the voids. Rather, it is to concentrate the chemical on top of the footing so that any joints, cracks or other openings in the footing will allow the soil on the underside to be saturated with the chemical that seeps through.

If the soil on both sides of the foundation is treated properly, the only entry route left for termites is through the bottom of the footing. Treating the soil below any openings through the footing blocks that one last route. If grade stakes have been left in the footing, it is doubtful that sufficient chemcial will soak into the small crevices around them to saturate the soil. This emphasizes the need to remove such stakes during construction.

Although tests have shown that there is only slight movement of the chemicals laterally or downward through soil, there should be concern for the possibility of contamination of wells on building sites. This is particularly true when the soil contains layers of gravel or if it tends to crack severely during periods of drought.

Where this is the case, it is doubtful that chemical treatment should be attempted if the well is within 50 feet (15 m) of the house. In such a case, it is safer to rely on physical barriers to the termites which were mentioned in the discussions of foundations, slabs, etc. Where the well is at least 100 feet (30 m) away, no practical danger exists.

If the house is between 50 and 100 feet (15 and 30 m) from the well, it is possible to treat safely by removing all of the soil adjacent to the perimeter of the building nearest the well by digging a trench 6 inches (15 cm) wide down to the footing. The soil so removed should be placed in a container and mixed with the prescribed amount of chemical. After it has dried, it can be replaced in the trench, which has been lined with a heavy plastic film.

One of the problems most often encountered when preventive soil treatment is being applied by a pest control firm is the lack of good coordination between the builder and the soil treater. There have been many cases where concrete was poured before the fill was treated. Or foundation voids were capped before they had been treated. Should there be such an occurence, the lack of treatment should not be ignored.

Rather, the concrete slab should be drilled and treated as will be described in the section on treating existing structures. The foundation likewise should be drilled and treated. The soil treater should be allowed ample time to do a thorough and complete job. A poor job is worse than none at all: it creates the false impression of security from termite invasion. In fact, later termite breaching of a poor treatment very often results in the need for a complete retreatment because of the difficulty in determining the exact extent of previous treatment. This is primarily a problem with slab construction, the most difficult and expensive to treat.

There is another concern that often arises in determining the procedures for coordinating the soil treatment with the construction schedule: how many trips to the site does it take for a treatment to be completed? There is no simple answer, but the theoretical minimum is two trips.

The first is to treat foundation voids (if any) and the soil to be covered by the building and and its attachments. The second trip is needed when all exterior grading and landscaping is completed. In practice, there are very few construction schedules that would allow such a few trips to complete the treatment. If there are several houses being constructed simultaneously in a development, the treater might do small segments of the jobs on numerous occasions when he is at the development site. If the job is a single dwelling isolated from others being treated in the vicinity, more careful planning is necessary.

For slab-on-ground construction, the first part of the treatment is usually applied when the foundation or its forms (monolithic) are in place and all of the fill has been completed. On that trip the treatment under the slab and in any foundation voids is applied. The second part of the treatment occurs when all of the fills, grading and foundations have been completed for carports, entrance platforms, etc., attached to the main foundation. The soil to be covered is treated. The third and final part of the treatment would be to the soil outside the foundation after all grading and landscaping is completed. Basement and crawl space construction would require similar steps in treating. Basically, when foundations are at least partially completed; when grading, fills and foundations for attached concrete slabs are completed and, if applicable, the basement floor is ready for the concrete to be poured; and when the outside grade is completed. Since protection of treated fills is required if the concrete is not poured the day of treatment, it is common to closely time the treating of dirtfills with the pouring of concrete. Careful coordination is critical and is often the weak spot in the system.

The question is often raised as to how to determine whether or not an adequate soil treatment has been applied. The ultimate test is afforded by the termites. If they breach the chemical barrier, it obviously was not adequate. Such a test could involve years of waiting and could include damage to the structure.

Soil treatment is recognized as an effective and essential type of protection. Unfortunately, there is little if any physical evidence of its presence. For this reason, efforts have been made to devise tests to determine that the desired treatment was actually applied to the soil.

There is currently a controversy over the correct procedure to follow in taking and handling soil samples for chemical analysis. The complexity of the compounds and the soil types and chemistry make a simple, accurate field test procedure unlikely. It is likely that immunoassay test kits, based on color reactions, will become available for the common termiticides. These field test kits will not determine the exact amount of pesticide found in a sample, but can detect very low levels and indicate the simple presence or absence of termiticide.

Even laboratory-analysed samples will not determine whether or not termite control will be obtained at the tested site, since soil samples are taken from scattered locations and only one untreated spot is enough to allow termite entry. They can determine whether or not a treatment has been applied at the site and thus have value in quality control work.

Other attempts have been made to develop methods to indicate the presence of the chemical. One involved the addition of dye to the treating liquid (Berzai, 1964). Some pest control firms place termite-susceptible wooden stakes in treated areas around buildings and examine them periodically to determine the presence or absence of termite activity. An attempt was also made to develop a practical bioassay technique to determine the amount of soil insecticide present (Coleman, 1966). This involved using live fruit flies as test animals exposed to soil samples. There are many practical limitations to the method, and it has never been widely used.

At present, the only accurate methods of determining the amount of insecticide present in soil samples all involve laboratory analysis. The accuracy of the analyses has been greatly increased in recent years, and the cost has not become unreasonably high, considering the improvement of the results. Finding generally accepted procedures for sampling and for handling and analyzing the samples is an important concern at present. Another problem lies in the lack of available research data on the breakdown of termiticides in soil. This needed research is in progress and more accurate information should be forthcoming. Once the needed data and procedures are available, laboratory analysis of soil samples may be widely used for regulatory and quality control purposes.

Efforts have been made to test building elements as to their resistance to termite attack. A wood-cement composite structural building board called "Century Board" (U.S. Patent 3,271,492 — 1966) has been field and laboratory tested and found to resist termite attack (Allen and Dolan, 1970). In this case, the Portland cement coating on the wood elements forms a physical barrier which the termites are unable to penetrate.

Several experiments involving the use of insecticides added to concrete at the time of mixing have shown that this is an effective method of rendering the surface of concrete toxic to termites. Gay and Wetherly (1959) substituted a 0.5 percent emulsion of dieldrin for the normal mixing water to prepare a termite-proof concrete.

The insecticide did not affect the strength of the concrete. A 75-percent dieldrin wettable powder added to concrete so that the concentrations of the toxicant in cement blocks were approximately 0.1 and 1.6 percent by weight resulted in 100 percent mortality to native subterranean termites exposed to the block surfaces for one minute a week after mixing (Allen et al., 1961). After 16 months, the newly cracked surfaces of laboratory-aged mixtures were equivalent in toxicity to the original surfaces of new mixtures (Allen et al., 1964).

Since termites conceivably might tube over the surface of insecticide-treated concrete before receiving a lethal dose, it was necessary to test treated concrete for such tube building. R. H. Beal (1971), of the U.S. Forest Service, Southern Forest Experiment Station, Gulfport, Mississippi, found in field tests that, after five years, concrete blocks incorporating chlordane at concentrations of 0.5 percent or more were not tubed over.

Blocks containing as little as 1/8 percent dieldrin were not tubed over. Such treatments in actual structures should be equally effective. However, at the time of this writing, chlordane and dieldrin are banned for any type of termite control. Since the tested pesticides are no longer available, substitutes which are as effective will have to be found if this system is to be considered further.

Since termite shields were for many years recommended for the prevention of subterranean termite attack it is logical that some comment be made on the current position of termite control specialists related to metal shields. To put it quite bluntly, termite shields have very rarely been of any practical value against termites. This is primarily because they were rarely installed properly. More often than not, they were damaged or altered during the construction process to the point that they were valueless, even if they were properly installed.

Add to that the fact that they can be breached by termites if they are left undisturbed long enough. The best that could be said for termite shields is that they forced termites out into the open where they could be seen. Because of the many practical problems with termite shields, they are no longer recognized as adequate physical barriers to termites.

■ INSPECTION

Any structure built entirely or in part of wood in areas where subterranean termites occur should be inspected at least annually for active infestations, regardless of physical and chemical preventive measures employed in its construction. Obviously, if no special barriers were incorporated, the need for inspection is more critical.

Even the best physical barriers currently employed may be breached by termites. Very careful application of soil insecticides is sometimes not effective in stopping termites under some circumstances. In addition, there may have been changes which have occurred subsequent to construction that have altered the integrity of termite barriers. For example, one or more service or repair persons may have left termite-prone conditions after working underneath or around the structure. The homeowner may have disturbed treated soil or placed wood on the ground near or under the structure. Vegetation may have grown over or through chemical barriers to provide termite access. Settlement cracks may have occurred in foundation walls or concrete floors.

If property is inspected annually, very little serious damage will result from subterranean termites before they are discovered and treated. They work slowly enough that their presence can be detected and the infestation controlled before structural weakness in timbers could result. In certain locations, or in certain conditions, it might be reasonable to inspect twice annually. Certainly, any situation of a supicious nature should be investigated as soon as it is observed, and reported by the building occupant.

■ THE INSPECTOR

A good inspector for termites must be willing and able to get into dark, dirty, hidden and often confined areas of a structure. He must be very conscientious and diligent in his examination because the evidence is sometimes very subtle and difficult to detect with only casual observations. In addition, he must have a good understanding of termite biology, habits and capabilities, as well as being thoroughly familiar with building design and practice.

■ THE PURPOSE OF AN INSPECTION

An inspection should determine the presence or absence of termites within the limitations of generally accepted inspection practices. Obviously, an inspection that would give absolute assurance of the presence or absence of termites would require the opening of walls and foundations to gain access to all structural members. This could easily cost more than an actual termite control treatment. Since most infestation will be revealed by careful visual inspection and sounding of structural members in accessible areas, this is the accepted basis on which inspection reports are made.

An inspection should determine the route of entry used by any termites that are found. It should also reveal conditions that are conducive to attack where none has yet occurred. Where damage is found, its extent should be determined and recorded.

■ THE EQUIPMENT REQUIRED

There is some variation in the equipment required, depending to some extent on personal preference, but also on the usual problems encountered in a given area. The most basic piece of equipment is a good light. This usually means one that is battery-powered, since cord-supplied electric lights are of limited practicality in many areas of buildings. The light must be reasonably lightweight and compact because of the confined spaces which must be reached.

A hammer is essential in sounding structural timbers, but has little value or none at all in examining finished wood. One or more slender probes, such as a knife, an awl, an ice-pick, or a screwdriver are used to test wood for the presence of termite damage or to scrape in narrow crevices to reveal termite shelter tubes. A slender piece of spring steel or a hacksaw blade is needed to insert underneath sills adjacent to possible dirt fills to determine whether there is soil in contact with wood on the hidden side. Protective clothing in the form of coveralls, bump cap and gloves is essential for safety as well as hygiene.

Some inspectors require such items as masons' rubber kneepads and compact dust respirators. Access to attics or other high areas usually requires a strong 6-foot stepladder. Finally, a good inspector will have a measuring tape for careful location of possible hidden spaces and to pinpoint damage sites. A clipboard and cross-section or grid paper complete the equipment list. The latter items are for reporting information and drawing a sketch of the structure to show the location and types of infestation and damage. Electronic listening devices and moisture meters will be of value in some situations, but a discussion of their proper use is beyond the scope of this manual.

■ THE INSPECTION PROCEDURE

For the inspection of structures in general, there are four parts to be considered: the examination of the exterior, the interior, the attic and the substructural area (basement or crawl space). Before beginning the actual examination, the inspector should interview the occupant of the house. The occupants' observations on things such as damage seen, plumbing or rain leaks, termite swarms, etc., can be extremely helpful.

■ EXTERIOR INSPECTION

First, make a circuit of the complete exterior, pacing or measuring the dimensions of the structure and recording an accurate outline on cross-section or grid paper. Include any attachments such as porches, patios, etc. This will enable you to more easily spot hidden, often inaccessible areas that might be overlooked when making interior and substructure inspections.

Note and record on the building outline any moist areas adjacent to the house and any evidence of improper drainage which might create dampness in the substructure.

Check for the number, size, condition and location of foundation ventilators. If there is an access to a crawl space, note whether it is wood and whether the frame is in soil contact. Watch for termite tubes between the frame and the foundation. This is a common entry point for termites.

Examine the entire foundation wall very carefully. Watch for termite shelter tubes on the surface. They are sometimes difficult to spot if soil has splashed onto the surface or if the tubes are in crevices, corners, etc. Look for vertical cracks in the wall and check them carefully for termite signs.

Note any vegetation such as vines, trees, grass, etc., in contact with the house or blocking ventilators. Note any cellulosic materials, particularly lumber or firewood, that is adjacent to the foundation. Adequate space for inspection should be provided or the obstructed area should be noted on the report.

Note the distance between the exterior grade and wooden structural members—including doors and windows set in the wall and wood siding. If there are decorative wood framed attachments to the house such as pilasters, arches, buttresses, etc., particularly if they are finished with stucco, note whether or not they are on foundations with adequate clearance. If they are hollow, note whether or not there is access for inspecting the interior. This is a common termite activity center. If they cannot be inspected, note the inaccessible areas on the drawing.

Particularly watch for earth-to-wood contacts and for wood embedded in or extending through concrete. Check such areas very carefully, including carefully probing into the wood surface to determine interior termite damage.

If the exterior of the foundation is finished with stucco or plaster, check by pounding carefully below the top of the foundation for a hollow sound indicating where basal stucco is loose. Loose basal stucco provides hidden access for termites and should be noted on the drawing.

Where there are structures or slabs attached to the main foundation, check for shrinkage cracks at the point of contact and carefully examine them for termite shelter tubes. If there is an attached planter, watch for soil above the sill line and for hidden access for termites between the planter and the house.

There are certain points involved with slab-on-ground construction that should be stressed. These include more likelihood of inadequate clearance between outside grade and wood and of earth fills being in close proximity to wood. Where there is a high exterior grade and loose stucco on a slab foundation, there is reason for particular concern. Sometimes there are access panels to plumbing under older slab houses. These should be removed so that under areas may be inspected.

In spite of the fact that the termites usually originate from the soil, do not forget to look up, particularly where Formosan subterranean termites are found. They often build shelter tubes or extend carton material on the outside of houses well above ground when they are working inside the walls. This happens less frequently with native species.

Also, look for discolored or stained areas which might be a sign of decay from a rain leak, which could also be an above-ground source of water for subterranean termites. Use an extension ladder, if necessary, to make a careful inspection above ground. Also, open and examine for termite signs the inside of any exterior electrical meter and fuse boxes set into walls.

Finally, note any fence or gate posts that are in contact with the soil and the house, particularly if there is wood siding. Examine them very carefully for evidence of termite activity and for shelter tubes extending from them to the house.

Record all of the information in your report and on the building outline as you go, so nothing is left to memory and forgotten as you evaluate the inspection later.

■ INTERIOR INSPECTION

Slab-on-ground construction is the most difficult type to inspect adequately for evidence of subterranean termite activity. Most of the termite entry points on the interior are hidden by floor coverings and interior finish and trim. This places a great deal of pressure on an inspector to make a very thorough inspection. A positive attitude and a willingness to try can do much to reduce the limitations that would otherwise result.

The most critical areas to inspect are the outside perimeter walls and areas over any known or suspected joints or cracks in the slab, especially expansion joints. The crevices between wood trim and the floor and wall are the primary points to examine. A good light played on the crevices or any area being inspected will reveal any signs of shelter tubes or sealing with soil or carton. If the crevice is large enough, insert a slender probe into it and attempt to drag out any soil, etc., that might not otherwise be visible.

Tap lightly on the surface of the baseboard, shoe molding, etc., to detect hollow sounds. Should a suspicious area be discovered, discreetly probe into the surface with a slender, pointed instrument to discover the extent and depth of damage. The same procedure is followed higher up on the walls inside of and around built-in cabinets and around door and window trim. Even the ceiling-wall joint should be examined, especially if it is covered by molding. It is not uncommon for Formosan subterranean termites to extend carton material onto the wall surface when they are working inside.

This is less common with native species. Sometimes the only evidence of termite activity on walls are slightly raised areas on the surface which crumble upon contact to reveal that termites have consumed the paper from between the gypsum and the paint on plasterboard. Wood fiber composition board is likewise damaged, the evidence being as subtle as that on plasterboard. Proceed in an orderly fashion throughout the house so that no wall section is overlooked.

Areas around plumbing and utility pipes, or open areas in the slab for plumbing, are also critical. If plumbing hatches are removable, they should be opened. Look not only for termite shelter tubes or carton material, but also for evidence of leaks or condensation. An above-ground moisture source can allow an infestation to flourish, even if the soil is later treated. Look for wooden form boards and stakes that may have been left in plumbing accesses through slabs and examine them carefully by probing and prying them out.

Finally, check floor coverings, including all types of carpets and tiles as well as wood. Look for slightly darker areas or split or raised areas on wood. Sounding, probing and discreet prying up small splinters where damage is suspected will serve to locate termite activity in wooden floors. Where carpets are concerned, the usual evidence is holes which have resulted from the termite consumption of the vegetable fiber carpet backing, leaving the wool or synthetic fibers loosened to be picked up by the vacuum cleaner.

Typical carton and soil material is found in the exposed opening. Termite damaged membrane floor coverings and tiles show irregular sunken areas where pressure has been exerted on them. Termites tunnel between the mastic and the top surface of a few types of such coverings, particularly linoleum.

Interior inspection of crawl space construction is not nearly so critical as with slab-on-ground. Evidence is usually more abundant in the crawl space than on the inside of the house, so damaged areas not found inside will likely be discovered in subsequent crawl space inspection. Inspection of the same general areas and in the same manner as those described in slab construction are the rule here as well.

It is probably not necessary to spend the same amount of time in this type as in slab construction. Concentrate on areas next to raised porches, terraces, planters, etc., where the soil line on the outside might be high. Also, areas around plumbing should be carefully examined, particularly for leaks.

Basement construction presents a combination of both slab-on-ground and crawl space inspection requirements. This is particularly true when the basement is finished. Inspection of the first floor of such a house is described for crawl space construction. Basement inspection will be covered with substructural area inspection.

■ ATTIC INSPECTION

Subterranean termites are not found in attics as often as they are in other parts of structures. However, no inspection should be considered complete without a close examination of attic space. It is not uncommon to find shelter tubes of subterranean termites in portions of the attic directly above earth-filled porches, hearths and closed-in concrete porches or patios.

The entire perimeter of the house should be inspected in a manner which will allow examination of the roof, wall and ceiling members which can be seen from the attic. Also, inspect around chimneys and plumbing vent pipes that penetrate from below. If there are rain leaks, particularly where there are flat roofs, subterranean termites will nest entirely in the attic space and work their way down into the wood of the structure. Watch for this possibility. There are often many things that can limit the ability of an inspector to make an adequate inspection of an attic.

In many areas, blown insulation obstructs the view of much of the wood. Sometimes there is little clearance in attics of low-pitched or flat-roofed houses. Excessive bracing may make inspection very difficult or impractical. Be sure to note any such limitations to visual inspection and sounding of wood. Should there be no access to an attic space, estimate its accessibility from the exterior and recommend the construction of an access opening if it seems practical.

■ SUBSTRUCTURAL AREA INSPECTION

Crawl space inspection is probably less difficult than many attic inspections, but it is nevertheless often not given proper attention. It involves crawling over broken bricks, chunks of concrete and other hard, sharp objects. It may be dirty and damp and confined in many areas. These conditions discourage careful inspection by poorly motivated inspectors.

Since subterranean termites can be detected more easily in crawl spaces than in other areas, it is an important portion to examine carefully. The size of the house will determine how the inspection should be carried out. Keep in mind that all perimeter foundation walls, all pillars, all interior bearing walls, all chimney bases and hearths, and all pipes making contact between soil and wood must be inspected. This might well mean making several trips back and forth across a crawl space in order to get a close look [no more than 10 feet (3 m) away] at all areas.

A good light can help reduce some crawling, but it is important to get close enough to see evidence that may be obscure. Having already examined both the exterior and interior, the inspector should have certain strategic points well in mind. These usually will be the location of earth-filled porches, patios, planters, damp areas, bathrooms and water-connected appliances.

Proceed in a regular pattern along foundation walls, around piers, underneath bathrooms, etc. Note the surfaces of the foundation wall and other masonry for shelter tubes. Check the wood on top of the foundation, piers, etc. for shelter tubes. Whenever they are found, try to trace them to their origin so that the point of contact with the soil or the moisture source may be determined.

Look for shelter tubes between the foundation and the sill, between the joists and the sill, and in any crevices or corners created by the joining of structural members. If double joists or laminated beams are involved, shine the light as deeply as possible into the crevices between the components to look for termite shelter tubes where the joist or beam contacts the foundation.

If it is not possible to see into such crevices, insert the thin probe or blade into them as deeply as possible in an attempt to dislodge any termites or their workings that might be present. Sounding and probing, with a good light to illuminate the area being examined, are critical.

As the inspector moves from one area to another, he should watch for wood debris, tree stumps, form boards and wooden stakes on or in the soil. Wood supporting plumbing lines or heating ducts should be inspected for infestation. Any such termite sources should be reported.

Areas around bathrooms, kitchens and sites of water-connected appliances should be examined carefully for signs of termites and water leaks that might allow them to survive above ground. Examine the pipes making contact with the wood or passing through the foundation wall to deterine whether termite tubes are on them.

During the course of the inspection, note any areas where clearance is less than 18 inches (45 cm) between the bottoms of floor joists and the soil and less than 12 inches (30 cm) between wooden beams and girders and the soil. Provision of adequate clearance is part of treatment, so the area involved should be carefully indicated on the diagram. Should any areas be inaccessible to inspection because of low clearance or foundation walls with no access openings, note these carefully on the report.

Basements may be easier to inspect than crawl spaces, but they incorporate features that require special consideration. A basement, if finished so that masonry or concrete walls are obscured, is inspected much as is slab-on-ground construction. When the basement is unfinished, or only roughly finished, a slightly different technique is involved.

The primary points of inspection are the base of the foundation wall at the junction with the floor and the top of the wall where wooden structural members rest on it. Look for termite shelter tubes on the wall, usually emerging from the floor joint. Inspect the plates of wooden partition walls and the bases of wooden support posts and stair carriages.

Note whether or not the wood is embedded in the concrete and probe very carefully if it is. Examine built-in wooden cabinets, shelves, etc., that are in contact with foundation walls or over slab joints or cracks. If there are wooden windows and doors set in the walls, examine the joints and crevices around them and sound the wood for hollow, damaged areas.

If there is a closed ceiling in a basement, it is not possible to examine the wood resting on top of foundation walls unless the ceiling is composed of suspended panels. In such a case, panels near the perimeter of the building should be lifted to allow inspection of sills, joists and beams resting on the wall. The inspection procedures described for crawl space construction apply here. Where this part of the structure cannot be inspected, note the inaccessibility on the report.

Termites also enter basements around plumbing and utility lines that pass through the floor or the foundation walls. Look for evidence of termites and for water leaks in these areas.

All other aspects of the inspection would be as described for crawl spaces.

INSPECTION OF GARAGES AND STORAGE AREAS

Although garages and storage areas may be separated from the house itself, they should be inspected. One of the problems often encountered in an inspection is that stored materials may obscure the view or the access of the inspector. All wooden members resting on the foundation should be inspected. Shrinkage cracks between concrete floors and foundation walls provide easy entry for termites. Voids in concrete block or brick foundations also allow termite entry.

If concrete foundations have vertical cracks, they become vulnerable. The same exterior conditions observed in other areas may occur around garages and storage areas. Watch for inadequate clearance between grade and wood and for termite tubes on the outside of the foundation. Piles of trash or stored firewood or lumber adjacent to outer walls are also hazards to note.

CONTROL

When a careful inspection has revealed that termites are infesting a structure, or that conditions exist which probably will lead to eventual infestation, control measures should be taken. The purposes of such measures are to immediately terminate damage to the structure and its contents and as completely as practical, to provide the equivalent of the proper design, construction and preventive treatment that could have been incorporated at the time the building was erected.

In practice, control measures tend to be based more on chemical treatment than on structural alterations. However, chemical treatment and mechanical alteration are both essential phases of termite control, and should be used in proper proportion.

The extent of treatment provided should be based on several factors. First, the type and quality of the construction involved is an important consideration. Some types, as discussed under "Good Design," are much more resistant to attack than others. The care with which the building was constructed, assuming good design, is also critical.

Second, the incidence of termite infestation varies from one area to another. If termites are rare in the location in question, a very minor amount of treatment may suffice; in other areas, the most complete treatment may hardly be satisfactory. Finally, economic considerations of the property owner must be incorporated into the decision. The purpose of treatment is to reduce economic loss. Simply put, the cost of treatment designated should not be out of proportion to the value of the property being protected.

MECHANICAL ALTERATIONS

Mechanical alterations, as related to termite control, have been defined (Rambo, 1980) as: any mechanical measures which render a structure less susceptible to termite attack or which render the immediate surroundings of a structure less favorable for termites. These measures include sanitation, breaking earth-to-wood contacts, installing physical barriers to termites, replacement and repair of damaged wood, providing adequate drainage, clearance and ventilation, and providing access for inspection of all vulnerable areas.

The discussion of mechanical alterations and the following discussion of chemical control will be of a very general nature. It would not be practical, or even necessary, to provide detailed information on such a complex subject. An excellent and definitive reference on the subject "Approved Reference Procedures for Subterranean Termite Control," published by the National Pest Control Association (Rambo, 1980), provides the details needed by those interested.

■ SANITATION

Sanitation, as used here, applies to the removal of all wood, paper and other cellulosic debris from the soil under or near the house. It is quite common for wood scraps to be left under buildings during construction. Property owners sometimes store firewood or lumber on the ground under or next to the house. This material provides an easily available soure of food for termites and sustains the colony until they can forage for new sources, including the structure itself.

■ OTHER MECHANICAL ALTERATIONS

The other procedures included in this category are more nearly associated with structural improvements that will increase resistance to termite entry, or will make termite activity more easily noticed. For example, a structure may have wooden members extending below concrete floors or in contact with the soil. These members should be cut off and concrete or masonry installed to support all wood above adjacent floor slabs or soil. The reader will recall that clearances of this type were discussed under the heading "Good Design."

Earth-filled appurtenances (such as porches) which abut foundations are a major source of termite entry. One of the best ways to correct this problem is to provide ventilation and permit access for treating and for inspection by constructing a tunnel to remove earth which contacts wood. An alternate method, often used on the West Coast, is to place a barrier of concrete, called a "seal-off," between the earth fill and the framing of the building proper.

In some cases the grade may be lowered to provide clearance between wood and soil. The construction of concrete or masonry gutters in an excavated trench below wood siding is an example. In other cases soil should be removed from crawl spaces with clearance less than that recommended.

Additional foundation ventilators often are needed to provide the recommended amount of net free ventilation area and to reduce dead air spaces. A vapor barrier applied to the soil surface can be used instead of additional ventilators in most cases.

Where drainage is a problem it can be handled in many ways. The construction of retaining walls and the excavation of soil to increase the flow of ground water away from houses is sometimes feasible. Simply directing roof water into drain lines emptying downgrade might solve the problem.

Providing access for thorough inspection and treatment is a very common necessity, especially when additions have been made to the original structure.

■ CHEMICAL TREATMENT OF THE SOIL

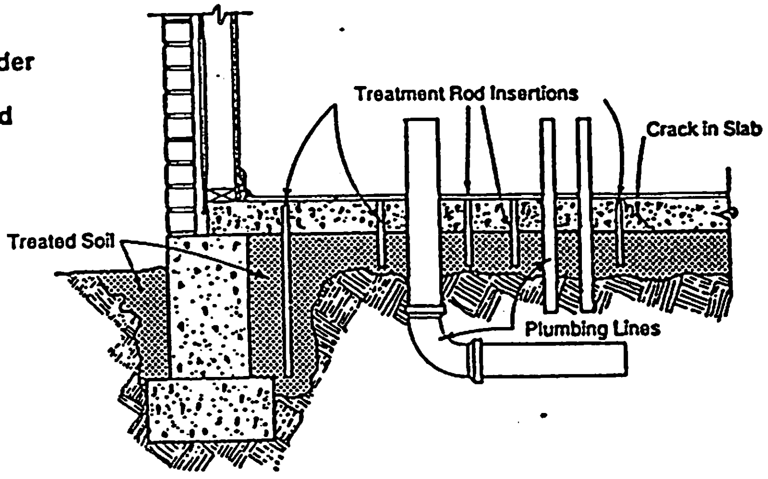
As indicated previously, chemicals are probably the most important factor in corrective termite control in all parts of the country.

The insecticides, concentrations and application rates are the same for control as for pretreating. The methods of application to soil in crawl spaces and adjacent to the outside of foundations are essentially the same as in pretreating. A combination of shallow trenching and grout rodding to the footing is the most common method. The thoroughness of dispersal is still the essential feature.

The treatment of slab-on-ground construction, or of dirt-filled extensions of raised construction, presents the greatest challenge to the termite controller. These types of construction are the most expensive to treat and are less certain of protection by the treatments than any others. The best way to treat the soil is by drilling a series of holes vertically through the slab. The holes should allow injection of the chemical into the soil below all joints, cracks or openings around plumbing.

The proper distance between holes is determined by the type of soil, its moisture content, and the experience of the applicator as treating proceeds. Again, the chemical barrier must be complete in order to be effective. The advantage of vertical drilling is that the chemical may be flooded over the surface of the soil. It is not uncommon for a space, due to soil settlement, to exist below any slab construction other than

FIGURE 2-14. Treatment under concrete slab with vertical rodding at joints, cracks and openings around plumbing.



floating slabs.

Termites may build tunnels over the bottom of such slabs from areas quite removed from joints or cracks. When such spaces are present, this requires rather extensive chemical treatment on the fill surface to reduce termite entry above treated soil. Special rod tips are available for this purpose. By using a grouting rod, the chemical also may be injected as deeply as needed into the soil to saturate it to the footing, etc. (Fig. 2-14).

In drilling vertically through slabs, there are hazards of drilling through radiant-heat pipes, hot air ducts and plumbing, or the possibility of ruining a vapor barrier, as well as the expense and liability incurred in removing tile, parquet, etc. To avoid these hazards, many applicators prefer to treat under slabs by drilling horizontally through the foundation at a height that allows rods to be inserted immediately below the slab.

This method is inferior to vertical drilling because there is very little downward movement of the chemical below the application point except in very loose, sandy soil. Also, if the holes in the foundation are too low, there may be untreated soil above the point of application.

Horizontal rodding is accomplished by using long treating pipes [up to 20 feet (6 cm) long] which are inserted and pushed through the fill as the chemical is applied. If they remain in the proper horizontal and vertical plane, accuracy of application is good. Unfortunately, such long pipes are sometimes deflected in the soil and may move into areas far removed from those anticipated.

A series of horizontal holes at rather close intervals will allow "short rodding" by inserting rods only a short distance into the fill and injecting the chemical to flood the soil between the application points. This method also has the disadvantage of not ensuring deep treatment below the point of injection. Most slab-on-ground houses present situations that preclude using either long rods or short rods exclusively. Figure 2-15 shows a typical example of a plan of rodding.

■ TREATMENT OF FOUNDATIONS

It was mentioned in the discussion of foundation types and their resistance to termite entry that termites use voids in foundations and flaws in footings to pass from the soil to the wood above the foundation. They often are able to accomplish this completely undetected when there is no physical barrier to force them into the open. Foundation treating of existing structures requires that the chemical be injected into all voids in the foundation wall, piers, chimney bases, etc., at or near the footing.

The chemicals, concentrations and rate of application are the same for treating existing structures as in pretreating. With some foundations the voids may be very regular and predictable, as in the case of hollow concrete blocks, coursed bricks or veneers. They also may be disconnected and irregular, as in the case of some brick foundations and rubble stone foundations. The treatment is applied by drilling enough holes deep enough and close enough together that the chemical will reach all parts of the footing surface.

Drilling should be as near the footing as is practical so that most of the insecticide reaches the footing instead of being absorbed on the surfaces of the masonry units. The primary purpose of treating the foundation voids is to puddle the chemical on top of the footing so that it may seep into any faults and treat the soil beneath.

TREATMENT OF WOOD

In the past, this has been a very minor step in subterranean termite control, but it has a real place in modern control procedures. Most of the termiticide used for soil treatment can also be applied by injection into wood. In addition, there are a number of other compounds and formulations that are marketed for this purpose. Label directions indicate that small diameter holes should be drilled at intervals into wood infested by termites and the insecticide injected with tapered nozzles under pressure into the termite galleries discovered.

Another product, containing the active ingredient sodium borate (Bora-Care), has recently been registered for teatment of wood in place. It is applied by brush or spray and when the recommended volume has been applied, it penetrates throughout the wood. This provides permanent treatment if the wood is not exposed to wetting.

The purpose of these treatments is to quickly kill the termites which would otherwise be cut off from the soil by the chemical barrier there. If there is sufficient moisture in the wood, these termites might survive long enough to find an alternate source of moisture above ground and continue their damage. This procedure has special importance when treating for Formosan subterranean termites, which

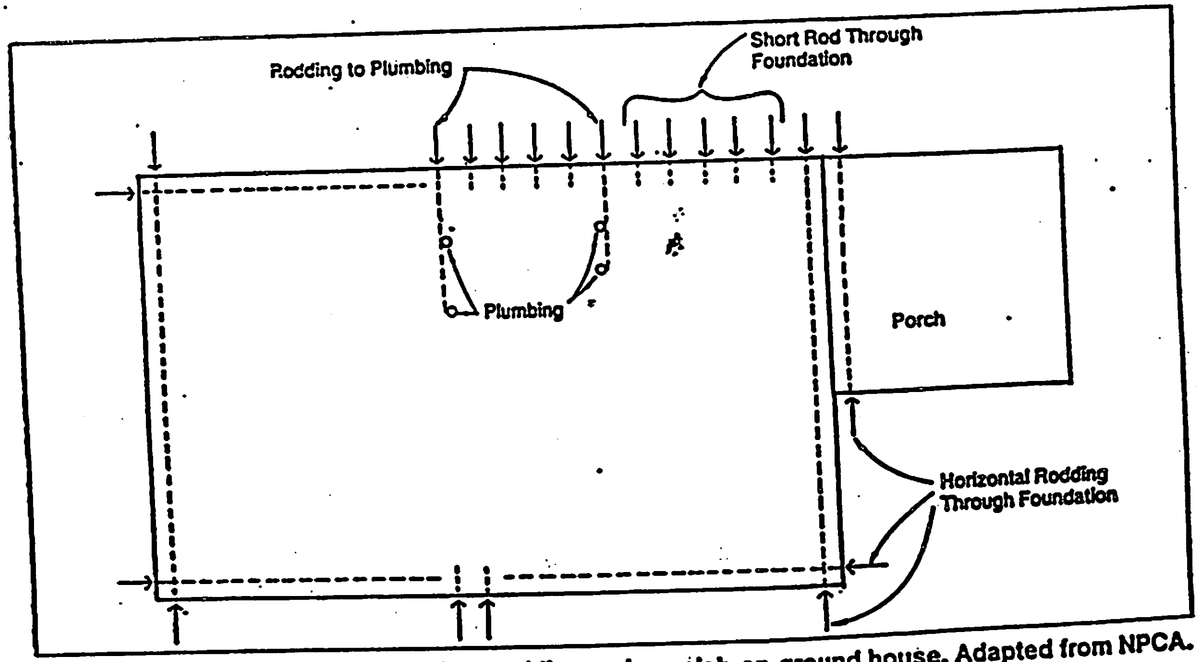


FIGURE 2-15. A plan for long- and short-rodding under a slab-on-ground house. Adapted from NPCA.

fill construction cavities with carton which holds moisture for long periods, even without an above-ground water supply. Also, if swarmers are present in moist wood, they may swarm out as much as 6 weeks after the soil has been treated and create questions about the effectiveness of the treatment.

Another use of this procedure occurs when there is a well or cistern in the crawl space and the soil cannot, according to the termiticide labels, be treated. Wood treatment provides some protection, even though it cannot replace soil treatment.

There are also times when subterranean termites have established a colony in wood without ground contact when there is a rain or plumbing leak to provide a constant supply of moisture. In addition to stopping the moisture source, treating the infested wood will speed up the control of the termites.

The use of chemically-treated wood in repair and in replacement of damaged wood is also considered as part of the control process. The application of spray- or brush-coats of insecticides onto wood, except for the borate salt solution mentioned above, are not effective for termite control. Primarily wood that has been pressure-treated with standard chemicals by standard procedures should be considered useful. Whenever such wood is cut into or sawed, the exposed surfaces should be retreated with two brush coats of wood preservative.

Other methods of subterranean termite control have been tried in the past, and some new ones are being investigated. To complete the picture, we need to look briefly at them.

■ OTHER TERMITE CONTROL PROCEDURES

Fumigation has been tried for the control of subterranean termites, but it generally has been unsatisfactory, except for the control of aerial (no ground contact) infestations of Formosan subterranean termites. Methyl bromide and sulfuryl fluoride (Vikane) are both used successfully. Formosans require about four times the dosage of Vikane needed to control drywood termites, which will be discussed later.

Arsenical dusts blown into shelter tubes have been successfully used to control several species of termites in Australia, but this procedure has not met with success when tried against our native species. No extensive testing has been attempted, and with the present concern over the toxicity of arsenic, none is likely.

Many laboratory studies have demonstrated the possibility of controlling subterranean termites through the use of pathogens. Both bacteria and fungi have been toxic to termites, but no field trials have yet been successful (Lund, 1971). The interest in this approach to control has continued (National Science Foundation, 1975; Zoberi and Grace, 1990) and may yet lead to some practical success.

The relationships of ants with termites have been studied. Though ants are considered to be among the major natural enemies of subterranean termites, studies have shown that not all species are antagonistic. Some species, however, have been reported to destroy colonies of termites (Beard, 1973). It is conceivable that manipulation of ant colonies might be used as an applied biological control measure against termites in situations where the ants would not be undesirable.

Two companies have marketed a species of entomogenous nematodes (*Steinernema feltia* Filipjev) known to infect and kill subterranean termites. Because they are not chemical pesticides, the EPA did not require their registration. Laboratory and field tests conducted by the USDA Forest Service Gulfport laboratory indicate that these nematodes do not eliminate or control termites when applied in the prescribed manner (Mauldin and Beal, 1989).

You may recall that termites communicate by laying down a pheromone trail. The active substance in this pheromone has been successfully synthesized and tested with several of our native subterranean termite species, as well as with the Formosan subterranean termite. They all responded positively, though to varying degrees (Matsumura, et al., 1972). The fact that it is possible to produce a single synthetic pheromone that acts strongly on several species of termites offers a possibility for practical field application.

A new approach to subterranean termite control was introduced when the use of poisoned blocks of wood which are acceptable to termites was found to be practical by Esenther and Gray (1968) and Esenther and Beal (1974). Beard (1974) modified their technique and had encouraging results. In general, the system consists of treating wood bait blocks with a slow-acting insecticide such as Mirex, and exposing the blocks in the vicinity of termite activity.

In most of the tests, the bait blocks had been partially decayed by fungus known to be attractive to termites. The use of decayed blocks increased the feeding by termites and probably speeded control. The excretion of Mirex-poisoned fecal material and the eventual disintegration of dead, poisoned termites added to the chances for physical contact with the poison in the workings. In the tests which were cited above, there was a significant reduction of termite activity or actual death of individual colonies. The amount of insecticide exposed in the environment by this method is extremely small. Mirex is no longer on the market due to environmental concerns.

There has been a concerted effort to find a replacement toxicant. This has become much more important since the spread of the Formosan subterranean termite. They have extremely large colonies spread over a large area so it is difficult to control them. If a non-repellent, slow-acting termiticide could be found to incorporate into the bait-block control program, it might be possible to eradicate entire colonies. The USDA Forest Service has conducted a number of laboratory and field studies (Mauldin et al., 1985; Jones, 1988) as well as some university researchers (Su et al., 1985; Su and Scheffrahn, 1990). Many of the candidate toxicants have been insect growth regulators which tend to cause an over-population of soldiers and/or presoldiers and, at some levels, cause the death of the termite gut fauna, resulting in their starvation.

So far, none of the field tests have provided adequate control. The search continues, using new slow-acting materials as they become available. An example is GX071, belonging to a new class of delayed action insecticides, the fluoroaliphatic sulfones (Su and Scheffrahn, 1988). Laboratory tests with this material are encouraging and field tests will follow.

Physical control of subterranean termites has been unsuccessfully attempted through the use of termite shields, as indicated previously. Recently, there has been renewed interest in this method because of the rediscovery that precisely-sized particles of sand and gravel will prevent tunneling by subterranean termites. When Ebeling and Pence (1957) first discovered the phenomenon, it was not pursued because of the availability of cheap and effective soil toxicants.

As tighter restrictions on the use and availability of termiticides have developed, new interest in the technique has emerged. Ebeling and Forbes have developed a system for using a layer of 12 grit (2.5-1.6 mm) sand-blasting sand to form a barrier against the western subterranean termite adjacent to house foundations. In Hawaii, researchers have determined that basaltic particles in size ranging from 1.7 to 2.4 mm will prevent the penetration of Formosan subterranean termites. Ebeling and Forbes indicate that the smallest particles are too large for the termites to push aside, and the largest particles are not large enough to allow these insects to crawl between them. Tamping the sand in place improves it effectiveness. We may well see this technique grow in its use.

DRYWOOD TERMITES

Wherever drywood termites are considered to be a major problem, serious consideration should be given to taking all economically feasible steps to prevent their attack on structures. This would, in general, be the Pacific area, southern coastal California, southern Florida, and the Caribbean area. Because these termites are of secondary importance in most areas where they generally occur, there has been less research done on methods of prevention and control than on the more important subterranean type.

Incipient infestations that are transported in infested articles outside their natural distribution areas do not pose serious threat of damage. Wherever they occur, outside of the high hazard areas mentioned above, their presence is more of a nuisance than a serious threat of rapid structural damage. Of course, they should not be ignored whenever they are discovered, but the extent of prevention and control measures should be geared to the actual potential for damage and the value of the property being protected.

PREVENTION

It is neither as practical nor as economical to prevent drywood termite attack as it is to prevent subterranean termites. There are, however, several measures that can be taken to reduce the chances of attack. The effectiveness of these measures is variable, and probably none of them used alone would be sufficient for entirely effective prevention. A discussion of the various measures and their effectiveness follows.

SANITATION

The very careful examination of any article of furniture, wooden crates, cellulosic building materials, etc. will help prevent the introduction of an existing infestation into a house under construction or into one already existing. Early infestations are difficult to discover, so thoroughness is essential.

In addition, it is helpful to examine all potential outdoor infestation sources nearby and to remove as many as possible, including stored lumber, firewood, scrap lumber, or dead branches or scars on living trees near the structure. Since it is common for drywood termite swarmers to be carried by the wind and to be attracted by lights when they swarm at night, this preventive measure is of limited value. In general, the older the neighborhood houses and the more old trees present, the more liability to infestation exists.

EXCLUSION

In the past, some authors have recommended screening vents to attics and crawl spaces to exclude drywood termite swarmers (Snyder, 1969). This is not satisfactory, since the screening must be 18 to 20 mesh to exclude the termites. Even when new, mesh of this small size greatly restricts normal movement of air, and it very quickly becomes clogged with dust and cobwebs.

Keeping a good, continuous coat of paint or varnish on all outside wood surfaces and keeping all cracks and joints tightly caulked might help some in preventing establishment of new infestations. Although drywood termites can penetrate through a flat surface, they much prefer to wedge themselves into a crevice to start boring. There are so many routes of entry other than exterior surfaces, however, that painting and caulking should not be relied upon very heavily. Drywood termites can enter under siding, through wood shingles, or between and underneath shingles or tiles and sheathing.

CHEMICAL TREATMENT OF WOOD

There have been reports of the successful prevention of drywood termite infestation in framing timbers by soaking the timbers in vats of wood preservative before construction. Others have suggested spraying or brush-coating all of the wood framing in a structure after it is erected but before it is closed in. Until recently, these preservatives have been organic chemicals which penetrated only the outermost portions of the treated wood.

Wood treated with organic preservatives by dipping or spraying before construction begins requires the brush application of preservative to each cut or notched surface in order to maintain the barrier against termite entry. The borate salt solution (Bora-Care), mentioned in the discussion of subterranean termite control, is also available for drywood termite control. It can be applied after all the cuts have been made in the wood and the structure is at the "dried in" stage. Since it diffuses deep into the wood and does not leave unless leached out, it offers a great measure of protection for wood that is used in protected locations. These methods have not, until now, been in wide or general use.

Pressure-treated wood is protected against drywood termite attack. Its use for all framing members, and possibly even for sheathing, subflooring, exterior doors, windows, and exterior trim, might well be justified in the high hazard areas mentioned previously.

Even with this method, there are limitations. Every place on the surface of pressure-treated wood that is cut, bored, notched, or split during the construction process must be retreated with a brush or spray application of the preservative. The difficulty of ensuring adequate treatment of such places has been a great limitation to the value of pressure-treated wood in the prevention of drywood termites.

■ DESICCATING DUST APPLICATION

Certain fluoridated silica aerogel dusts (Dri-die 67) have been found to be effective in preventing drywood termite attack. Ebeling and Wagner (1964) described a system of applying such dusts during construction in attics, crawl spaces, and wall voids to prevent drywood termites. The silica aerogel has a monomolecular layer of ammonium or magnesium fluorosilicate which gives it an electrostatic charge, resulting in a more efficient deposit on dusted surfaces and efficient "pickup" by insects crawling over them.

Insects are protected from desiccation by a very thin waxy layer on the surface of their external skeleton. Sorptive dusts, such as the silica aerogels, absorb enough of the protective wax layer to cause a lethal rate of water loss. For termites, only a barely visible film of such dust is necessary to protect wood.

The dust is applied at the rate of 1 lb. per 1,000 sq ft (0.45 kg/93 sq m) to attic spaces. An electric dust blower or a water-type fire extinguisher, commercially available for the application of insecticide dusts, is used to disperse the dust in a high velocity airstream. The unusually light weight of this dust allows it to coat wood surfaces evenly throughout the attic and into its extremities. Under-area framing is likewise treated. Ebeling and Wagner (1964) also encouraged the application of fluoridated silica aerogel to wall voids at the rate of about 1.25 lb per 1,000 sq ft (0.57 kg/93 sq m) of floor space. Since this type of dust is inorganic, it should not deteriorate and should be effective for the life of the building. In addition to killing drywood termites, it is lethal to many other insect pests that inhabit the treated areas.

■ USE OF STEEL OR CONCRETE CONSTRUCTION

The use of steel, concrete, stone, or brick in construction offers excellent protection from drywood termites. This type of construction will not, however, prevent infestations of wooden trim and built-in fixtures or of wooden furniture inside the buildings.

■ INSPECTION

Structures should be inspected annually for the presence of drywood termites. The longer they have infested a building, the more difficult their control. At first their galleries are extended rather slowly and may be easily accessible for treatment. Later they may extend their workings into framing within walls, and control becomes much more difficult and more expensive.

Many of the same principles and procedures discussed under inspection for subterranean termites apply equally for drywood termites. The same equipment is used and the same areas are inspected. There are enough differences in specifics, however, to require some detailed discussion of them. Be sure to record all damage on the outline of the structure as you proceed.

The extent of drywood termite infestation in a building needs to be determined as fully as possible. An appropriate control method can only be chosen when the extent of infestation is known. Unless a general fumigation of the whole structure is planned, the extent of each of the one or more infestations in the building needs to be carefuly delimited for treatment.

Only in this way can less than complete fumigation produce satisfactory control.

■ EXTERIOR INSPECTION

As with subterranean termites, it is important to make an accurate diagram of the structure. Careful measurement of outside dimensions will reduce chances of overlooking inaccessible or hidden portions of the building. It becomes even more imporant to observe the roof structure and any dormers, new extensions, etc., that might not be accessible from the main attic space.

The inspector should move around the structure slowly while observing the sides of the house from roof to ground. The roof eaves, rafters, and trim should be closely observed for evidence of damaged wood, and especially should be checked for fecal pellets dropping from above. Pellets will be too scattered to be observed on the ground, but they are often caught in spider webs and on ledges. It may be necessary to use a ladder to closely observe areas high on the side of the house.

If there is wood siding, it should be carefully examined for areas of damage and for pellets. The same is particularly true for window frames, sills, and sashes, which are quite vulnerable to attack, especially where the exterior of the house is stucco, masonry, or non-cellulosic material. A meter box set into the side of a house should be opened and examined on the interior for the presence of drywood termite fecal pellets.

The foundation of the house needs careful inspection if ventilator openings have wooden frames that might be infested. A wooden access and its frame also should be carefully checked for drywood termite damage. If there is a plumbing inspection door set into the foundation of a slab-on-ground house, open it and inspect for evidence of drywood attack in any wood involved.

■ INTERIOR INSPECTION

The occupant of the house should be carefully questioned as the interior inspection begins. Asking about any areas of damage or suspicious looking areas might well speed up the process of locating termite activity.

Proceed in a logical order when inspecting each room, so that no area is overlooked. Starting at the door, examine it and its frame and trim very carefully for signs of drywood termite damage. Sound it very carefully with the handle of a probe or with your knuckles. Look for fecal pellets that may be in crevices or in more conspicuous places beneath the place where the door stands open, if it is an interior door. Move to the baseboard in a clockwise or counterclockwise direction.

The baseboard on the perimeter walls of houses is a common site of infestation. If there is a wooden floor, examine it carefully as you proceed. Notice whether or not there are any "oddly" placed scatter rugs, tables, etc. If the house is for sale, especially, the owner is not likely to go out of the way to disclose damage. The unusual arrangement may be covering up floor damage. If damage is found in flooring, note its position carefully on the diagram so that, if there is a subarea to be inspected, the underside may be more thoroughly examined. Window sills are an excellent place to look for fecal pellets indoors. Also examine any molding at the ceiling. If there are wood fiber composition ceiling panels, they can be infested, and also should be carefully examined. The evidence may be very subtle and will require very careful inspection. Sound and probe to delimit any infestations discovered.

In the bathroom area, find and remove the plumbing inspection panel. Look inside for drywood termite pellets. The kitchen also requires some special attention. Built-in cabinets are often infested. In addition to examining them externally, remove the drawers and open the doors to look inside. Termites often infest the counter tops on their undersides, so look up as well as for pellets on shelves. Look at the floor covering to see if there is evidence of damaged flooring underneath that may have given way in small areas and left small, irregular depressions in the linoleum or tile. Record any suspicious areas so that they may be inspected on the underside.

Places that are warm, such as enclosures around hot water heaters or trim around wall furnaces, should be very carefully checked for termite activity.

Exposed beams, wood paneling, and parquet flooring are also subject to attack and require special attention.

Wooden furniture and other articles are often the source of infestation indoors. Be sure to examine underneath them for signs of pellets. If a piece of furniture is infested, check the wood floor under it to see if the infestation has moved down into it.

■ ATTIC INSPECTION

Upon entering the attic, look over the entire area below the roof rafters, ridge pole, etc., for any accumulations of fecal pellets. Move around the perimeter of the building at the junction of the roof rafters and the wall plate. Notice particularly whether there are pellets in this area. Any evidence here probably means the infestation is also in the wall below. Examine all rafters and the ceiling joists below in a pattern that will not allow any to be overlooked. Check the top plates of all partition walls and all support framing between rafters and joists. Use a hammer to sound the wood and a probe to explore suspicious areas for cavities.

Heavy piles of termite pellets can mean that there is extensive termite activity in the area or it can mean that carpenter ants have moved into termite galleries and are removing the pellets to enlarge their nest area. Probe into wood when this condition is found so that the insects involved can be determined.

If portions of the attic are inaccessible for inspection, make a note on the diagram and recommend that access be provided. Inaccessibility can be caused by anything such as roof extensions, firewalls with no access doors, carports, dormers, etc. When a complete attic is inaccessible due to lack of an access opening, determine whether or not there is sufficient space between the roof and the ceiling so that it can be inspected. If so, recommend that access be provided before an inspection report is completed.

Many attics have blown-in insulation between the ceiling joists. This limits the inspector's ability to make a complete inspection and should be noted on the report. Termite pellets can be seen on top of the insulation when they fall from above, so the remainder of the inspection can proceed as usual.

■ SUBSTRUCTURAL AREA INSPECTION

Inspection of crawl spaces for drywood termites primarily involves examining the sills and joists at the perimeter of the building. Pellets often accumulate on top of the sill or on the soil below.

If the wood floor on the interior of the house is infested, look carefully at the subflooring and the floor joists below it for additional damage.

Basements that are unfinished are inspected much like crawl spaces. If they are finished, they are inspected much like the interior of the house above.

■ INSPECTION OF GARAGES AND STORAGE AREAS

These areas are particularly subject to drywood termite attack. In California, Ebeling (1975) found that when garage doors are usually left standing open during the day, there is a higher incidence of infestation. As with subterranean termite inspection, stored articles may make inspection difficult. Nevertheless, all exposed wood should be inspected both inside and outside. Wood shelves and cabinets should not be overlooked. Sounding and probing are also needed to confirm and pinpoint infested sites.

■ CONTROL

The control method to be used for a particular drywood termite infestation is determined primarily by the extent of their activities. If there are only a few infested areas and they do not appear to have been extended into walls, inaccessible parts of the attic, etc., treatment would be quite different than if the infestation is widespread and partly inaccessible.

In the latter case, there is no choice but to fumigate the entire structure, an expensive procedure. Other cases may be treated less expensively, though less effectively, by other methods. Whatever method of control is used, it is advisable to consider treating the attic with desiccating dust to reduce chances of reinfestation.

■ THE DRILL-AND-TREAT METHOD

If the infestation has been carefully delimited by sounding and probing and it all appears to be accessible to treatment, the drill-and-treat method can provide satisfactory control if the applicator is very skilled and conscientious.

The traditional method involves drilling 1/4 inch (7 mm) holes at 1-foot (30cm) intervals into infested members so that access to all termite galleries is provided (Fig.2-16). An insecticide is then applied into the holes. There are dust formulations of boric acid, silica aerogel, and bendio-carb (Ficam) presently labeled for drywood termite control. Only small amounts should be applied: about 1 ounce (28 cc) of dust is enough to treat 15 to 30 holes. Too much dust will plug the galleries, and they will be walled off by the termites and isolated. The treatment holes are plugged with wooden dowels or corks. This method relies on the habit of grooming among termites.

Through grooming, only a few termites with insecticidal dust on their bodies can spread it to all of the colony.

There are a number of insecticides which can be injected into drywood termite galleries as water emulsions. They include the organophosphate, chlorpyrifos (Dursban); a carbamate, propoxur (Baygon); and three pyrethroids, cypermethrin (Demon); fenvalerate (Tribute), and permethrin (Dragnet).

Chlorpyrifos is also available as a solution in a pressurized container (Whitmire PT 270 Dursban).

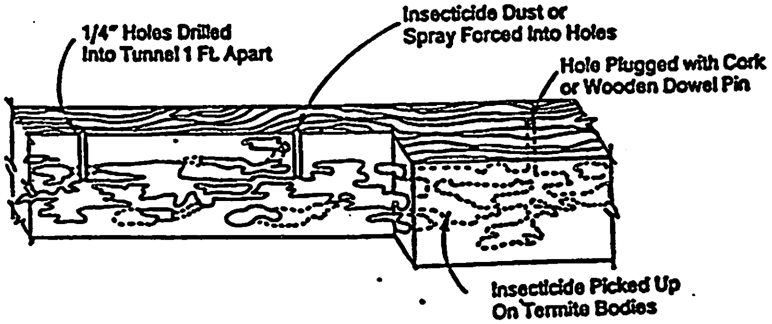
■ FUMIGATION

Although fumigation is generally recognized as the most effective treatment for drywood termites, there are some negative factors that should be considered. Fumigation is a hazardous procedure and should be undertaken only by experienced and licensed fumigators. It offers no protection against future infestation of the treated structure. It is necessary for the occupants of buildings being fumigated to vacate the premises for at least a day and, in some cases, for several days. Finally, it is an expensive procedure that, in some areas, must be repeated at intervals of 5 to 7 years because of reinfestation.

The basic procedure is to enclose the entire structure in a gas-tight tarpaulin made of nylon fabric coated with rubber, neoprene or plastic. Where fumigations are not performed on a regular basis, tarpaulins are replaced by heavy plastic sheets. The edges of the tarpaulins are rolled together and clamped at close intervals with strong steel clips. The bottom edge is held in close contact with the soil and against the house foundation with sand or with long, slender, sand-filled canvas bags which are called "sand snakes."

Stucco structures with flat roofs are sometimes sealed with special gas-tight paper over

FIGURE 2-16. The drill-and-treat method of drywood termite control.



outer doors, windows and ventilators if the fumigator believes a satisfactory seal can be obtained without the labor of "tarping."

By whatever method the building is enclosed, the exterior wood such as window and door frames, siding and trim must be effectively exposed to fumigant. These exterior members could support small infestations that might not be controlled if the fumigant were applied only to the interior of the building.

The fumigants most commonly used to fumigate structures for drywood termites are sulfuryl fluoride and methyl bromide. They are introduced into structures through long plastic or copper tubes leading from large cylinders of compressed gas. Electric fans circulate the fumigant to prevent stratification. Sulfuryl fluoride is generally used at the rate of 1 lb per 1000 cubic feet (0.45 kg per 28 cu m) of building space and methyl bromide at 2 to 3 lbs per 1000 cubic feet (0.91 to 1.36 kg per 28 cu m). The gas usually remains in the building for 24 hours. The choice of actual dosage and exposure time is based on many factors, such as temperature, air movement, condition of tarpaulins, porosity of the soil under the building, etc. All this means that the knowledge and experience of an expert fumigator is needed to ensure success.

Sulfuryl fluoride has certain advantages over methyl bromide and has become the most widely used fumigant for drywood termite control. It is more penetrating and effective against two of the common termite species (Stewart, 1966; Bess, 1971; and Minnick, et al. 1972) and it has the added advantage that it is not necessary to remove any furnishings from the house during exposure. Methyl bromide costs less than sulfuryl fluoride, but rubber products containing residual sulphur must not be exposed to it. A reaction between methyl bromide and sulfur produces a compound with a garlic-like odor that may persist for years. Foam rubber is the worst offender and it is present in some carpet pads and upholstered furniture. Some kinds of leather are also susceptible, and shoes, for example, must be removed from the building.

In those situations where an entire building is not to be fumigated and there are drywood termite-infested articles in the building, they can be removed and fumigated separately. They either should be wrapped in a gas-proof tarpaulin or placed in a fumigation vault when they are exposed to the fumigant. The rate and duration of exposure are determined by the conditions during fumigation.

■ APPLICATION OF SILICA AEROGEL AFTER OTHER TREATMENT

Following treatment, most termite control technicians recommend attic dusting with silica aerogel to prevent reinfestation (Ebeling, 1975). In cases where termites survive treatment or were not detected for localized treatment, attic dusting provides a means of limiting the spread of surviving colonies. Also, during the swarming season, houses are subject to reinfestation from colonies outside the building. Any wood coated with the silica aerogel film would be protected from new infestation.

■ NON-CHEMICAL CONTROL

Because of public concerns over pesticide toxicity and sensitivity to chemicals, there has been an effort to find alternatives to their use in the control of drywood termites (Hall, 1988). Some of these methods are controversial, but have won over some users in the pest control industry and have been touted in the media.

One of the oldest of these non-chemical methods involves the use of high-voltage, low-amperage electricity applied to wood with a hand-held, AC-pulsing generator called the Electro-Gun. It has been in use since the early 1980s and is said to provide control of drywood termite infestations which are in accessible wood (Beck, 1987), a characteristic shared with the drill-and-treat method. It is also used by fumigators to re-treat local re-infestations.

Forbes and Ebeling have described a system for heating the air inside infested buildings to temperatures that are lethal to insects. Dubbed "thermal pest eradication," it involves blowing 140-150° F air from a portable propane furnace through a flexible duct into the infested building which has been at least partially covered with a tarpaulin. The temperature within the infested wood must reach at least 120° F for thirty minutes and this may take up to six hours. The system has been contracted to Isothermics, Inc. of Anaheim, CA, to provide licensing, training, and consulting services to the pest control industry.

Finally, the other extreme of temperature has been incorporated into a system for freezing termites in wood. Liquid nitrogen is forced into wall and ceiling voids which have been found to contain drywood termite activity through the use of fiber optics. In the Blizzard System, as it is called, liquid nitrogen is applied through small holes drilled into the voids. About 40 minutes later the temperature of the wood has dropped below 0° F, which freezes the termites. Only those areas of the structure which are accessible for inspection and for confining liquified nitrogen are suitable for this control procedure.

DAMPWOOD TERMITES

Prevention of, inspection for, and control of dampwood termites is primarily a matter of following the same measures used against wood decay. Since these termites must maintain contact with damp wood and damp wood decays, it follows that preventing or eliminating dampness in wood will prevent or control dampwood termites.

Because some species of these termites sometimes enter wood through soil, it is helpful to treat the soil as for subterranean termites to prevent their establishment in those locations, primarily in the desert Southwest, where the termites display this habit.

TREE-NESTING TERMITES

Tree-nesting termites can be prevented from entering buildings by treating them in the same manner as recommended for subterranean termites. Inspecting for tree-nesting termites would be very similar to inspecting for subterranean termites, since they build shelter tubes. They do build carton nests indoors occasionally, and these should be looked for. Once they have entered a building, they can be controlled by directly treating the carton nest (indoors or outdoors) with insecticides (personal communication, July 1975, Luis F. Martorell, Professor Emeritus, Department of Entomology, University of Puerto Rico, Rio Piedras, Puerto Rico).

There are at present four formulations of termiticides that may be applied in this way. They include water emulsions of cypermethrin (Demon), fenvalerate (Tribute), and permethrin (Dragnet). Chloropyrifos is available as a solution in a pressurized container (Whitmire PT 270 Dursban).

CHAPTER 2 • REFERENCES

Allen, T. C. and J. W. Dolan.
1970. Wood-cement composite as a deterrent to termite infestation. J. Econ. Entomol. 63: 1669-1670.
Allen, T. C., G. R. Esenther and E. P. Lichtenstein.
1964. Toxicity of dieldrin-concrete mixtures to termites. J. Econ. Entomol. 57:26-29.
Allen, T. C., G. R. Esenther and R. D. Shenefelt.
1961. Concrete-insecticide mixtures toxic to termites. J. Econ. Entomol. 54: 1055-1056.
Beal, R. H.
1971. Concrete impregnated with chlordane or dieldrin not tubed over by subterranean termites. J. Econ. Entomol. 64: 1289-1291.
Beal, R. H. and F. L. Carter.
1968. Initial soil penetration by insecticide emulsions used for subterranean termite control. J. Econ. Entomol. 61:380-383.
Beal, R. H., J. K. Mauldin, and S. C. Jones.
1989. Subterranean termites—their prevention and control in buildings. USDA Home and Garden Bull. No. 64. 36 p.
Beard, R. L.
1973. Ants as predators of *Reticulitermes flavipes*. Environ. Entomol. 2: 397-399.
—.
1974. Termite biology and bait-block method of control. Conn. Agric. Expt. Stn. Bull. 748. 19 p.
Beck, J.
1987. Electrogun demonstrates limited effectiveness. Pest Control 55 (5):32,34.
Berzal, L. J.
1964. Dye in spray tank helps to trace insecticide placement, penetration. Pest Control 32(9):46.
Bess, H. A.
1971. Control of the drywood termite, *Cyptotermes brevis*, in Hawaii. Hawaii Agric. Exp. Stn. Tech. Bull. 87:5-31.

Carter, F. L., C. A. Stringer and R. H. Beal.
1970. Penetration and persistence of soil insecticides used for termite control. Pest Control 38(10): 18-20, 22, 24, 62.

Coleman, V. R.
1966. A bioassay technique to determine amount of termite control insecticides in soils. Pest Control 34(1):32, 34, 36, 38.

Ebeling, W.
1975. Wood destroying insects and fungi. Pages 126-216 in W. Eberling, Urban entomology. Univ. Calif. Div. Agric. Sci., Berkeley.

Ebeling, W. and R. J. Pence.
1957. Relation of particle size to the penetration of subterranean termites through barriers of sand or cinders. J. Econ. Entomol. 80:690-692.

Ebeling, W. and R. E. Wagner.
1964. Built-in pest control. Pest Control 32(2):20-32.

Esenther, G. R. and R. H. Beal.
1974. Attractant-mirex bait suppresses activity of *Reticulitermes* spp. J. Econ. Entomol. 67:85-88.

Esenther, G. R. and D. E. Gray.
1968. Subterranean termite studies in southern Ontario. Can. Entomol. 100:827-834.

Gay, F. J. and A. H. Wetherly.
1959. Termiteproofing of concrete. Construction Review (Australia) 32(9):26-28

Hall, R.
1988. Freezing, frying and baking drywoods. Pest Control 56(3):42,44,45.

Hickin, N. E.
1971. Termites; a world problem. Hutchinson and Co., London. 232 p.

Jones, S. C.
1988. Field evaluation of several bait toxicants for subterranean termite control: a preliminary report. 19th annual meeting of the International Research Group on Wood Preservation. Document. No. IRG/WP/1376, Stockholm, Sweden.

Kard, B. M., J. K. Mauldin, and S. C. Jones.
1989. The latest on termiticides. Pest Control 57(10):58,60,68.

Lund, A. E.
1971. Microbial control of termites. Pages 385-386 in H. D. Burges and N. W. Hussey, eds. Microbial control of insects and mites. Academic Press, New York.

Matsumara, F., D. M. Jewett and H. C. Coppel.
1972. Interspecific response of termites to synthetic trail following substances. J. Econ. Entomol. 65:600-602.

Mauldin, J. K. and R. H. Beal.
1989. Entomogenous nematodes for control of subterranean termites, *Reticulitermes* spp. (Isoptera:Rhinotermitidae). J. Econ. Entomol. 82(6):1638-1642.

Mauldin, J. K., S. C. Jones, and R. H. Beal
1985. Termite control with bait blocks. Pest Control Technol. 13(3):38-40.

Minnick, D. R., S. H. Kerr and R. C. Wilkinson.
1972. Control of *Cryptotermes brevis*. J. Econ. Entomol. 65:1577-1579.

National Science Foundation
1975. Isolation of bacteria seen bringing termite control without pesticides one step closer to reality. Natl. Sci. Found. news release, NSF PR75-62, July 3, 1975.

Rambo, G. W. (ed.).
1980. Approved reference procedures for subterranean termite control. Nat. Pest Control Assoc., Vienna, VA.

——.
1990. Gulfport lab update; how long are termiticides effective? Pest Mgt. 9(8):25.

Smith, V. K.
1968. Long term movement of DDT applied to soil for termite control. Pestic. Monit. J.2:55-57.

——.
1969. Termite control and the natural environment. Pages 101-104 in Proceedings 1969 Termite Symposium. Brit. Wood Preserv. Assoc., Cambridge, England.

Snyder, T. E.
1969. Control of non-subterranean termites. USDA Farmers' Bull. 2018, 16p.

Spear, P. J.
1970. Principles of termite control. Pages 557-604 in K. Krishna and F. M. Weesner, eds., Biology of termites, Vol. II Acaddemic Press, New York.

Sperling, R.
1967. Protecting buildings against termites. Pest Articles and News Summaries. 13(4):345-374.

Stewart, D.
1966. Balanced fumigation for better termite control. Down to Earth 22(2):8-10.

Su, N. -Y.
1990. Measuring termiticides. Pest Control 58(9):24,30,34.

Su, N. -Y. and R. H. Scheffrahn.
1988. Toxicity and lethal time of N-ethyl perfluorooctane sulfonamide against two subterranean termite species (Isoptera:Rhinotermitidae). Florida Entomol. 71(1):73-78.

Su, N. -Y. and R. H. Scheffrahn.
1990. Economically important termites in the United States and their control. Sociobiology 17(1):77-94.

Su, N. -Y. and R. H. Scheffrahn.
1990. Potential of insect growth regulators as termiticides: a review. Sociobiology 17(2):313-328.

Su. N. -Y., M. Tamashiro and M. I. Haverty.
1985. Effects of three insect growth regulators, feeding substrates, and colony origin on survival and presoldier production of the Formosan subterranean termite (Isoptera:Rhinotermitidae). J. Econ. Entomol. 78:1259-1263.

Zoberi, M. H. and J. K. Grace.
1990. Isolation of the pathogen *Beauvaeria brassiana* from *Reticulitermes flavipes* (Isoptera:Rhinotermitidae). Sociobiology 16(3):289-296.

CHAPTER 3

WOOD-BORING BEETLES

INTRODUCTION

Beetles, belonging to the order Coleoptera, vary in length in this country from less than 1/25 inch (1 mm) up to about 3 inches (76 mm). Most of those which attack wood in structures are very small, less than 1/4 inch (6 mm) long. There are a few such species that approach 1 inch (25 mm) in length.

All beetles have chewing type mouthparts in both the adult and larval stages. The most characteristic feature of the beetles is the structure of the wings. Most beetles have four wings, with the front pair thickened, leathery, or hard and brittle, usually meeting in a straight line down the middle of the back, covering the thin, membranous hind wings which are folded under the front wings when at rest. The order name, Coleoptera, means "sheath wings" and refers to the characteristic front wings.

Figure 3-1 shows a typical adult beetle with the wings on one side spread to show their structure. Beetles undergo complete metamorphosis during their development. The damage by beetles to wood is primarily done by the larval stage (Fig. 0-2A).

Among wood-boring beetles, the larvae are all yellowish-white with dark mandibles (jaws) and sometimes with other dark areas or structures. This stage is always found inside the wood and is rarely seen, except for the larger species, even when damaged wood is split open.

The order Coleoptera is the largest order and contains about 40 percent of the known insect species. There are more than 30,000 U.S. species in over 100 families. We will be concerned with only a very few of these. There are three families which contain species that all are commonly considered to feed on seasoned wood. Other families have a few species of significance as pests of seasoned wood. Several other families have representatives which damage wood during seasoning and might later be encountered in structures. Still other families have species that do all of their damage to wood before it is seasoned. However, when the wood has been milled and placed into use, the damage done earlier is still visible and must be recognized.

The damage to wood that is done by beetles varies according to the species involved, but all types of beetle damage are different than that done by termites. When beetles have completed their development and have become adults inside of wood, they bore holes to the outside which are known as exit holes or flight holes.

These holes vary in size and shape according to the beetle involved. The real damage to the wood is discovered only when it is exposed by prying or splitting open the surface. In the case

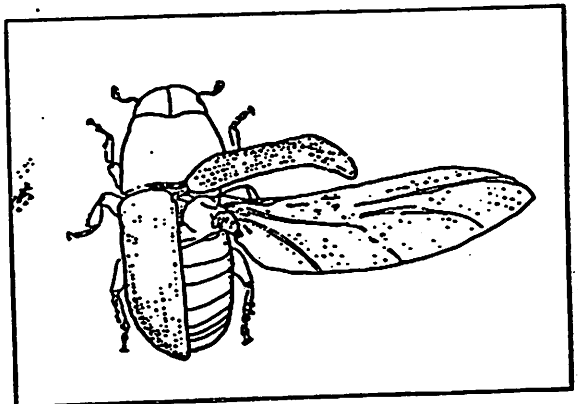


FIGURE 3-1: Typical adult beetle with the wings on the right side spread to show their structure. From Certification Training Manual for Structural Pesticide Applicators edited by R. Kaae and E. D. Young, Kellogg West, Center for Continuing Education, California State Polytechnic University, 1975. Used with permission.

of the more important wood-boring species, there are many galleries of different diameters, running primarily with the grain of the wood. They are most often packed with wood fragments and fecal material called "frass".

Some species of minor importance in structures do not fill their galleries with frass, but leave them clear and push the debris to the exterior through openings left in the surface. The function of wood-boring beetles in nature is the same as that of termites. They help reduce dead wood to a form that can be utilized for new growth by plants.

The amount of damage that might be inflicted to wood by beetles in any given location will vary according to many factors. Some of these factors include the presence or absence of certain beetle types in the area in question, the type of wood (hardwood or softwood), the part of the wood involved (sapwood or heartwood), and the environmental conditions present at the infestation site. As each family of beetles is discussed, these factors will be considered and related to the problem of evaluating the potential damage to the wood in the structure.

There are a number of wood-inhabiting beetles which will not be mentioned. Some of them could conceivably cause minor damage to wood later used in houses or could infest wood in a superficial way after it is incorporated into a house. Adults of these beetles could also emerge indoors from firewood. It is important to concentrate on those beetles which actually cause damage that might lead to structural weakness or which might require replacement of wood for aesthetic reasons. The approach of the author in the following pages will be to describe and discuss the important types that they may be identified as such and their potential for damage determined.

When an inspector encounters beetles or damage that does not fit the descriptions of those discussed here as having economic significance, there should be a reluctance to prescribe any preventive or control procedures until there is confirmation from a reliable source that the evidence encountered does, in fact, indicate a need for action. An example of a reliable source for confirmation would be the entomology department of a state university.

POWDERPOST BEETLES

The most important group of beetles that attack seasoned wood in such a way that preventive and control measures against them should be employed are the powderpost beetles. The term "powderpost" refers to a type of damage in which the inner portion of wood is eventually converted to a mass of powdery or pelleted frass held together by a thin outer shell of surface wood which is itself penetrated by numerous exit holes.

Damage of such an extent usually requires that several succeeding generations of beetles reinfest the same piece of wood. There is no general agreement among specialists in the field as to exactly which beetles should be classified as "powderpost beetles," or even that the term should be used.

The term originally applied to beetles in the family Lyctidae. Later, it became common to refer to beetles in the families Anobiidae and Bostrichidae as powderpost beetles. Their damage is quite similar to that of lyctid beetles. More recently, certain beetles in other families which cause powderposting have also been included. The author has chosen to restrict the term to the members of the first three families mentioned. They will be discussed in alphabetical order, since it would be difficult to assign them any order of economic importance on a national basis.

The lyctid powderpost beetles are sometimes said to be second only to termites in their destructiveness to wood and wood products. That may be true if all types of damage are included. It is not true if the rating is based on damage to wood in houses only.

ANOBIID POWDERPOST BEETLES

Powderpost beetles in the family Anobiidae are often referred to collectively as "death-watch beetles" or "furniture beetles". These are unfortunate choices of names, since they are misleading. Only one species of anobiid powderpost beetle found in structures is truly a deathwatch beetle. The name comes from a superstition that the sound made by the beetles tapping their heads on the wood as a mating signal is a sign that death is near. It is thought to have originated because the sounds are best heard when things are quiet as they would be late at night when someone is staying up with an ill person. The deathwatch beetle has been introduced into this country from England, but it has never become widespread or of much significance. It feeds only on decaying hardwood.

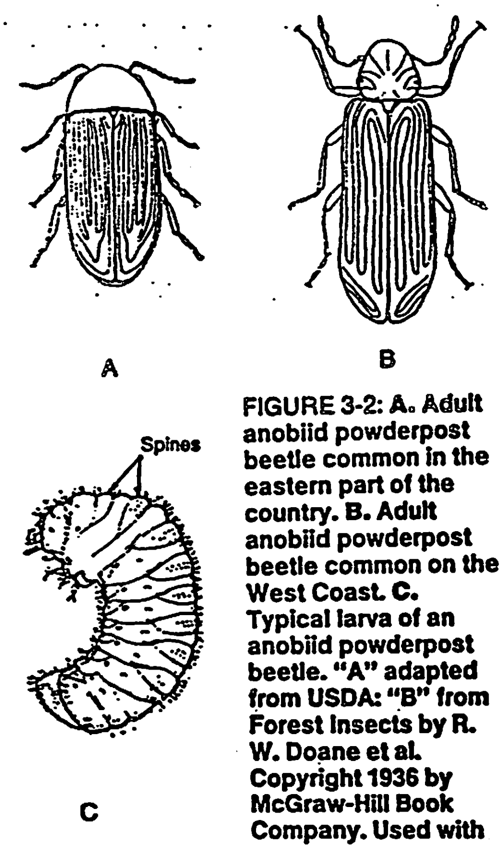


FIGURE 3-2: A. Adult anobiid powderpost beetle common in the eastern part of the country. B. Adult anobiid powderpost beetle common on the West Coast. C. Typical larva of an anobiid powderpost beetle. "A" adapted from USDA: "B" from Forest Insects by R. W. Doane et al. Copyright 1936 by McGraw-Hill Book Company. Used with permission of McGraw-Hill Book Company.

THE COMMON FURNITURE BEETLE

The common furniture beetle, *Anobium punctatum*, is also a European species that has been introduced into this country. It has wide distribution but is not of great economic importance here. It is the most common anobiid in buildings in many parts of Europe, Australia and New Zealand. The name "furniture beetle" derives from the fact that in years past they very commonly attacked furniture. This is not so much the case today, even in Europe, where central heating in living quarters dries out the wood in furniture to a level below that which is conducive to beetle development. In this country, furniture is infested much more often by lyctid powderpost beetles than by anobiids.

■ FAMILY CHARACTERISTICS

There are more than 200 species in the family Anobiidae in the U.S. Most of them are woodborers, but relatively few are pests of wood in use. There are two common species, the drugstore beetle and the cigarette beetle, that are important pests of stored products.

The adults of species that are commonly found attacking wood in buildings range from 1/8 inch to 1/4 inch (3 mm to 7 mm) in length. They are elongate and very convex. The pronotum (segment just behind the head) is hoodlike and, when viewed from above, completely conceals the head (Fig. 3-2A and B). Their color ranges from reddish brown to nearly black. Some have short hairs of lighter color covering their bodies. Most have conspicuous grooves and/or rows of pits on their wing covers.

The larvae are grublike, C-shaped and nearly white except for a brownish head and mouthparts. They are rather hairy and have rows of small spines on the top of most segments (Fig. 3-2C). The largest species, when full grown, are nearly 7/16 inch (11 mm) long when extended.

DISTRIBUTION AND ECONOMIC IMPORTANCE

Various species are found in all of the contiguous states as pests of wood in houses. They are not reported as pests in tropical areas. They are rather minor pests in heated, occupied dwellings in most parts of the country, except in the southeastern states, where they are most common. Their prevalence in the Southeast is influenced by the fact that a high percentage of houses in the region have crawl spaces which potentially provide conditions in wood framing which are well suited for anobiid beetle invasion and development. Anobiids are particularly common in the coastal areas where the soil water table and the relative humidity are high, thus allowing the moisture content of the wood to remain relatively high, the importance of which will be discussed later. In general, the drier the climate, the less the problem. One species has been reported as common on the West Coast. In the Northeast, they are primarily found in unheated houses or outbuildings.

It is very difficult to generalize concerning the economic importance of anobiid beetles in the country as a whole. They occur more commonly in some areas than they do in others. Where they have infested a house, no matter what the extent of infestation is, the parts of the infested building that might later be invaded and the amount of damage that might be inflicted is more dependent on factors within the structure than on the environment in general. For that reason, each infestation must be evaluated separately.

BIOLOGY AND HABITS

Some anobiid species will attack both hardwoods and softwoods, others only one type. *Euvrilletta peltata* (Harris) [formerly *Xyletinus peltatus*], although the most common species is southern yellow pine framing timbers in the Southeast, actually prefers hardwoods if given a choice. Anobiids usually feed on sapwood, though heartwood adjacent to sapwood may be damaged. Both freshly seasoned and older wood are attacked. Unlike the other powderpost beetles which will be discussed, the anobiids, according to those studied, can digest the cellulose of wood cell walls with the aid of yeast cells in their digestive tracts. The wood cell contents, such as starches, sugars and proteins, are the more critical nutrients.

The females of anobiid beetles lay eggs on the surface of wood under splinters, in cracks, under debris, or in old exit holes. Relatively few eggs are laid, probably fewer than 50 for most species. There is usually a high rate of survival of the eggs, but many larvae die before they can bore into the wood in order to find food and protection from natural enemies. After the larvae have bored straight into the wood a short distance, they turn at a right angle and begin to tunnel in the direction of the wood grain. They feed first on the softer springwood (early wood) and primarily in the outer sapwood if they have a choice. As the larvae develop, they molt many times. Each time, the tunnel they bore becomes larger to accommodate the increase in size. Often, the tunnels of many larvae intersect and the wood may even become a mass of wood fragments and fecal pellets which are packed in the gallery behind the larva as it tunnels. It usually takes at least 2 or 3 years for the larva to complete its development. If the moisture content of wood is below about 14 percent, or if it has very little food value (low protein or high resin content), the life cycle is prolonged, or development ceases and the larva dies. High temperatures are also unfavorable, both because of direct effect and because they tend to dry out the wood. If the wood is slightly decayed or has a relatively high moisture content, even near the fiber saturation point (30 percent), development goes at its best rate. Dampness and moderate temperatures in crawl spaces or outbuildings are particularly suitable. In nature, they live in dead limbs or bark-free scars on trunks of trees. When larval development is complete, a portion of the gallery where feeding was occurring is enlarged and cleared of frass and pupation takes place, usually in the spring. The adults which develop from the pupae bore holes straight to the surface of the wood and emerge. Most species of anobiids are active as adults during the spring and summer months, with most of the activity occurring during the first half of the warm season of the year. They do not feed, but actively seek a mate and, once the female is fertilized, the cycle is repeated. Most species of anobiids are strong fliers, and the females can move to new sources of food to lay their eggs. In spite of this, a large proportion of the eggs that a female lays are likely to be deposited on the piece of wood from which she emerged. This results in constant reinfestation of wood until little is left except the outer surface, unless something interferes with the beetles' activities.

The adults of some species are active during the day, others only at night. These beetles are not conspicuous and are not likely to be noticed unless they are found around light sources such as on windowsills or in spider webs at foundation ventilators in crawl spaces. Some species are attracted to lights at night.

■ SIGNS OF INFESTATION

The early stages of an infestation—before the emergence of the first generation of adults—are all but impossible to detect by usual methods. Because the development time is long and there is no external evidence of the attack until adults emerge, one or more generations may occur before there is enough evidence to be readily detected. This evidence is powdery frass and tiny pellets which accumulate underneath infested wood or are found streaming from the exit holes (Fig. 3-3A and B). The exit holes are round and vary from 1/16 to 1/8 inch (1.6 to 3 mm) in diameter. If there are large numbers of holes and the powder is bright and light-colored, like freshly-sawed wood, the infestation is both old and active. Sometimes infestations die out naturally, and the frass which remains is yellowed and partially caked on the surface where it lies.

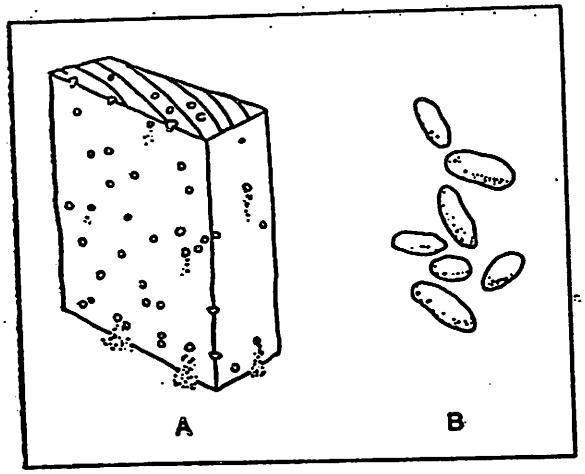


FIGURE 3-3. A. Wood infested with anobiid beetles. B. Enlarged view of fecal pellets of anobiid beetles from Certification Training Manual for Structural Pesticide Applicators, edited by R. Kaae and E. D. Young, Kellogg West, Center for Continuing Education, California State Polytechnic University, 1975. Used with permission.

The pellets are partially digested wood that has passed through the gut. These pellets (Fig. 3-3B) differ from those excreted by drywood termites: they are smaller and they taper toward each end. Some species produce bun-shaped pellets. Two hardwood-attacking species produce no pellets; their damage can be distinguished from that of lyctid powderpost beetles primarily by the fact that their frass is tightly packed in their galleries, whereas that of the lyctids is not.

■ CHARACTERISTICS OF DAMAGED WOOD

Tunneling is most extensive in sapwood, through it may extend into heartwood, particularly if it is partially decayed. In sound timber, damage is most severe in the outer sapwood nearest the bark, due to the higher protein content. Some plywoods are attacked, particularly if they are made with blood or casien glues which provide a source of protein for developing larvae. Synthetic adhesives appear to be toxic to small larvae.

The frass in the galleries is at least loosely packed and does not tend to fall freely from the wood unless the wood has dried out considerably since the attack occurred.

In most heavy infestations there are very tiny round exit holes, about 1/32 inch (0.6 mm) in diameter, scattered over the infested surface.

These are emergence holes of parasitic wasps, the larvae of which feed on the beetle larvae.

POTENTIAL FOR DESTRUCTION

Many factors are involved in determining the amount of damage that can ultimately be expected from anobiid powderpost beetles. The most critical factor in terms of spread of destruction is probably the amount of moisture present in the wood. Basically, the damper the wood, up to the fiber saturation point, the quicker the development. If the early stages of decay are present, damage goes even faster. Because of this, damage is usually greatest in the damper parts of houses. The extent of damage which ultimately could be done depends mainly on the proportion of sapwood to heartwood and, where wood from fast-grown trees is used, structural weakness can result. Most types of chipboard, hardboard and insulating board are not attacked.

Infestations normally increase slowly over the years, and a house is usually 10 or more years old before damage becomes obvious. With the advent of central heating and air conditioning in houses, the potential for serious widespread damage in houses decreased. The heat in the living areas, and that which rises to the attic, tends to dry out the wood of wall and roof framing and of interior trim, etc., as does cooled and dried air. If a house has no problem with excess moisture in the basement or crawl space, has central heating and cooling systems, and does not remain closed up and unoccupied for long periods, widespread, extensive damage by anobiid beetles is unlikely.

BOSTRICHID POWDERPOST BEETLES

The wood-boring species in the family Bostrichidae are sometimes referred to as "false powderpost beetles" or "large powder-post beetles." This is to distinguish them from the lyctids, which were first to be called powderpost beetles. General references designate them as "branch and twig borers" because the natural habitat of these beetles is in dead or dying branches of trees, particularly hardwoods.

FAMILY CHARACTERISTICS

The family Bostrichidae contains many species, the larvae of which bore in wood and cause typical powderpost damage.

The adult beetles are usually reddish-brown to black, the typical species found indoors being 1/8 to 1/4 inch (3 to 6 mm) long. They are elongate and cylindrical. The heads are directed downward and are hidden by the pronotum (segment just behind the head), as in the anobiids. The pronotum is often rather rough and rasp-like on the front edge. The wing covers are concave at the posterior end and, in some species, have projecting spines along the edges of the concavity (Fig. 3-4A). One destructive species is unlike the others and must be described separately. The black polycaon is a cylindrical, coal-black beetle 1/2 to 1 inch (12 to 25 mm) long. Unlike most of the species in this family, the head is prominent and extends forward. The pronotum is oval and not hoodlike and has no rough projections (Fig. 3-4B).

The larvae of bostrichids are grublike, characteristically curved and wrinkled, with the front half larger than the back half. They have six well-developed legs. The head is small and slightly darker than the creamy-white body. The mandibles (jaws) are black. They have few hairs on the upper portions of their bodies. They vary in size according to the species, most being 3/16 to 5/16 inch (5 to 8 mm) long. Figure 3-4C shows a typical example.

DISTRIBUTION AND ECONOMIC IMPORTANCE

Most of the contiguous states have recorded bostrichid species in wood indoors. Although the family has more species in the tropics than in temperate climates, none are serious pests in structures in the Pacific or Caribbean areas. One pest species native to India has become established in Florida and is encountered in imported hard- and softwoods elsewhere. The black polycaon occurs naturally in the West Coast states and, to a lesser extent, the Rocky

Mountain states. It is shipped to other parts of the country in infested wood products.

The economic importance of the bostrichid beetles in houses is much less than that of the other two families. They are most important as pests in hardwoods, and those species that attack wood of conifers rarely cause serious damage. Most of the hardwoods attacked are not those commonly used for interior floors, woodwork, and trim. Many of the species do not reinfest wood after it is seasoned, so the damage is limited to that inflicted by one generation, though that can be considerable.

■ BIOLOGY AND HABITS

Most species in this family breed in sapwood of hardwoods, but a few attack conifers. Some attack freshly cut and partially seasoned woods with the bark on; others attack relatively dry wood. These beetles can digest only the cell contents of wood, primarily starch, so are greatly restricted in the portion of the wood that can be utilized. The outer sapwood is the primary breeding site.

The females of bostrichid powderpost beetles differ from those of the other two families in that they bore into the wood and prepare "egg tunnels" for laying their eggs. The eggs are very slender and are inserted into pores in the wood that have been exposed by the cross-grain tunnel. The adults are active primarily during the summer months. The larvae which hatch from the eggs usually require almost a year to complete their development. As they grow, they molt many times and increase the size of their tunnel each time. The larvae pack the frass very tightly in the tunnel behind them as they feed. Under most circumstances, the larvae complete their development in the spring of the year following the egg laying. The larvae make the pupal cells slightly nearer the wood surface than the feeding galleries. The adults emerge by cutting straight through the surface. The adults feed on the wood as the egg tunnels are being prepared by the females. Mating occurs when the tunnel is partially completed.

Many of the adults are active during day and can be seen crawling over the wood. The black polycaon is active at night and sometimes even becomes a nuisance pest when it is attracted to lights in large numbers.

There are some exceptions to the generalizations on biology given above. Several small species that attack freshly sawn softwoods normally reach maturity in one year, but may require up to 5 years if the wood dries rapidly. They are found primarily when bark edges

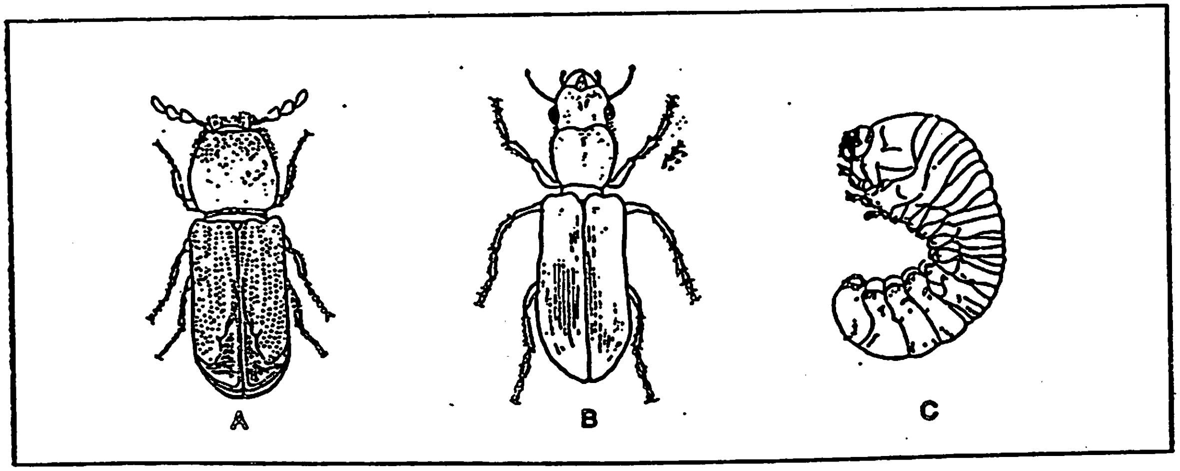


FIGURE 3-4. A. Typical bostrichid powderpost beetle. B. Black polycaon, an atypical bostrichid. C. Typical bostrichid larva. "A" and "B" from Forest Insects by R. W. Doane et al. Copyright 1936 by McGraw-Hill Book Company. Used with permission of McGraw-Hill Book Company.

have been left on framing timbers. There are records of the black polycaon emerging from wood 20 or more years after the infested piece was incorporated into a structure (Middlekauff, 1974).

SIGNS OF INFESTATION

The first signs of infestation are the circular entry holes for the egg tunnels made by the females. They may be 3/32 to 9/32 inch (2.5 to 7 mm) in diameter. The exit holes made by adults are similar, but are more apt to be filled with frass. The frass is meal-like and contains no pellets like those found in anobiid frass. It is tightly packed in the galleries and does not sift out of the wood easily.

The adults are not often seen unless there is a very heavy infestation and the inspection is made by coincidence at a time of beetle activity.

CHARACTERISTICS OF DAMAGED WOOD

In addition to the entry and exit holes in the surface, the interior of the sapwood may be filled with very round tunnels of different sizes, from about 1/16 inch (3 mm) up to 3/8 inch (10 mm) in diameter, depending on the species involved (Fig. 3-5). If damage is extreme, the sapwood may be completely consumed. Because of the shorter life cycle of bostrichids, they often cause more extreme damage more rapidly than would an equivalent population of anobiids. They are, however, restricted to the outer sapwood, and damage will usually not extend more than an inch or two into a board. This is usually of no consequence in framing timber, but might require replacement of some flooring or trim.

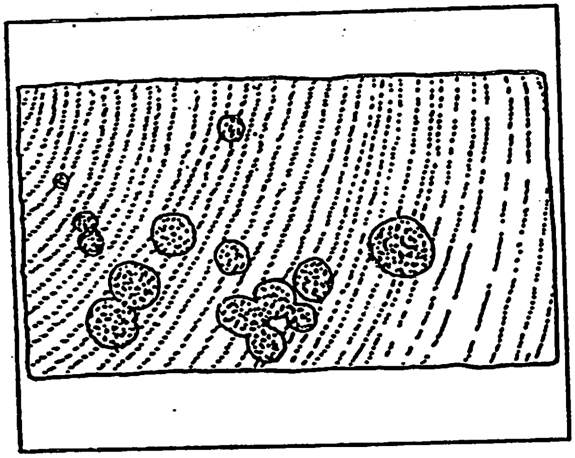


FIGURE 3-5. Damage of the black polycaon. From Certification Training Manual for Structural Pesticide Applicators edited by R. Kaae and E. D. Young, Kellogg West, Center for Continuing Education, California State Polytechnic University, 1975. Used with permission.

POTENTIAL FOR DESTRUCTION

The bostrichids offer very little likelihood of causing serious damage to softwood framing in a home. Because of the speed and completeness of their attack on portions of wood having a high starch content, they might cause serious damage to individual pieces of hardwood flooring or trim. There is little danger of reinfestation after the first generation emerges.

LYCTID POWDERPOST BEETLES

These were the first wood-destroying beetles to be referred to as "powderpost beetles." For that reason, some authorities use the term "true powderpost beetles" when classifying them. Some authorities indicate that they are the most destructive of the powderpost beetles occurring in North America. This is true for hardwoods and products made from hardwoods. Lyctids are, however, at present much less important than the anobiid beetles as pests of wood in houses. Problems with the prevention of lyctid powderpost beetles, particularly in imported hardwoods, has led to an increase in the number of infestations in such things as hardwood paneling and trim, as well as in furniture stock, etc. This could lead to a change in their relative importance in houses.

FAMILY CHARACTERISTICS

The classification of the family was revised by Gerberg (1957). He described all 35 native species. Most of them are quite similar in appearance and biology, so that separating them to exact species is not necessary to provide adequate control recommendations. The lyctid beetles are small, slender, somewhat flattened, elongate, reddish-brown to black, and vary in length from about 1/8 inch to slightly over 1/4 inch (3 to 7 mm). The head is prominent and not covered by the pronotum as in the other two families of powderpost beetles (Fig. 3-6A). Mature larvae vary in size but are usually less than 1/4 inch (6 mm) long. They are typical, curved, wrinkled, grublike larvae. They are enlarged at the thorax and have six distinct legs. They have relatively few, light-colored hairs on their bodies. The head is slightly pigmented, and the mandibles (jaws) are darker (Fig. 3-6B).

■ DISTRIBUTION AND ECONOMIC IMPORTANCE

There are species of lyctid powderpost beetles found in all of the contiguous states and in all U.S. territories. Some are native, and some are established introduced species. Several species are commonly intercepted at seaports in imported wood products.

The lyctid powderpost beetles are not considered to be of any great concern in houses in the Pacific area (personal communication, May 1976, Jonathan T. Kajiwara, Entomologist, Department of the Air Force, CINCPACAF (DEMM), Honolulu, Hawaii) or in the Caribbean region (personal communication, July 1975, Luis F. Martorell, Professor Emeritus, Entomology Department, University of Puerto Rico, Rio Piedras, Puerto Rico.) In the contiguous states they are relatively common in all parts of the country, but probably are of more concern in the South than in other areas.

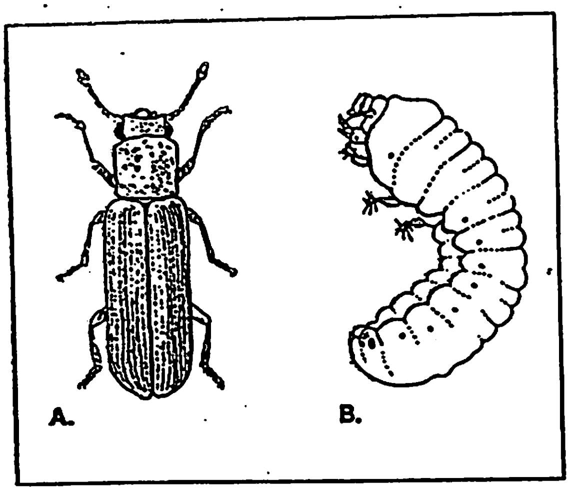


FIGURE 3-6. A. Typical adult lyctid powderpost beetle. B. Typical lyctid larva. "A" from Forest Insects by R. W. Doane et al. Copyright 1936 by McGraw-Hill Book Company. Used with permission of McGraw-Hill Book Company.

As indicated in the introductory remarks, lyctid powderpost beetles have been much less of a problem in the past than they might be in the future. The application of knowledge of the habits of these insects to the handling of hardwood lumber and the use of contact insecticides had reduced the lyctid problem to one of comparative unimportance in relation to its status 30 or more years ago (Bletchly, 1967). Because of restrictions on the residual insecticides used to treat stored hardwood products, and because some infested hardwood is being imported, the problem is likely to remain at a significant level. There has been a concerted effort by the USDA Forest Service and university research laboratories (Barnes et al., 1989) to evaluate the potential for borate salts as wood preservatives. Much progress has been made in their use, particularly in treating unseasoned tropical hardwoods. This should eventually reduce the problem.

■ BIOLOGY AND HABITS

These beetles attack the sapwood of hardwoods only. Ringporous hardwoods such as oak, hickory and ash are most susceptible. Some diffuse porous hardwoods that are often attacked include walnut, pecan, poplar, sweetgum, and black cherry. Many species of tropical hardwoods are also subject to infestation.

Lyctid powderpost beetles attack wood with a moisture content between 8 and 32 percent. This means that they infest partially or wholly seasoned wood (Christian, 1940, 1941). The greatest lyctid beetle activity occurs in wood with 10 to 20 percent moisture content (NPCA, 1961). Most wood within residences would be in this range.

Their chief source of food is starch and other cell contents, such as sugar and protein. The larvae cannot digest cellulose and other components of the cell walls. Lyctids are reported not to lay eggs in sapwood with a starch content less than 3 percent, and the greater the starch content, the better they thrive. The females taste the wood to test its suitability.

The amount of starch in wood depends on the tree species involved, the season the tree is cut, and the method by which the lumber is dried. Kiln-drying retains more starch than air-drying. Also, the older the wood, the lower the starch content. If given a choice, females lay their eggs on recently dried wood.

The female places her eggs inside the springwood vessels or pores. These are exposed when the wood is sawn, or the beetle may open them by cutting across the grain of the wood surface. Some species have also been reported to deposit eggs in cracks or crevices. Most species lay an average of 20 to 50 eggs. When they hatch, the larvae bore down the vessels at first, enlarging the tunnels as they grow. The tunnels are straight and with the grain at first, but later become more irregular and often intersect other tunnels. The mature larva bores to a point just under the wood surface and forms a pupal chamber. The pupal stage completed, the adult beetle cuts its way to the surface, forming a circular exit hole. Some of the very fine, flourlike frass produced by the larva is pushed out as the adult emerges.

The greatest period of adult activity occurs in late winter or early spring. The adults conceal themselves in cracks and holes in the wood during the day and become active at night. They are strong fliers and may be attracted to lights. Indoors, they may be seen crawling on windowsills, floors, furniture, and other surfaces.

The entire life cycle for most species requires 9 to 12 months. One common native species routinely completes a cycle in about 4 months. Any of them will develop more quickly if temperature, moisture and starch content of the wood is favorable.

■ SIGNS OF INFESTATION

Wood which has been infested only a short time will show no external evidence of beetle attack. If the first generation of adult beetles has emerged, there will be circular exit holes on the surface which are 1/32 to 1/16 inch (0.8 to 1.6 mm) diameter, depending on the species of lyctid and on the nutritive value of the wood: a given species will grow larger in wood with high starch content than it will in wood with little starch. The presence of small piles of fine flour-like wood powder (frass) on or under the wood is an even more conspicuous evidence of infestation (Fig. 3-7). Even a slight jarring of the wood makes the frass sift from the holes. There are no pellets as in the anobiids, and the frass falls easily from the wood rather than being packed in as in both the anobiids and bostrichids.

It is not likely that the adult beetles will be seen by an inspector, unless dead ones are found on window sills or in spiderwebs. The larvae are, of course, always inside the wood.

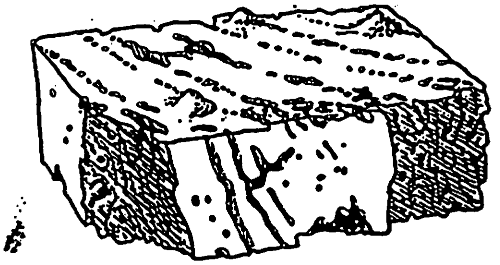


FIGURE 3-7. Wood damaged by lyctid powderpost beetle. From Certification Training Manual for Structural Pesticide Applicators edited by R. Kaae and E. D. Young, Kellogg West, Center for Continuing Education, California State Polytechnic University, 1975. Used with permission.

CHARACTERISTICS OF DAMAGED WOOD

The sapwood of infested wood has longitudinal, cylindrical galleries of various sizes, most of them about 1/16 inch (1.6 mm) in diameter. They are loosely packed with fine frass that falls freely from the wood when it is split open. If the damage is severe, the sapwood may be completely converted to frass held in by a very thin veneer of surface wood with beetle exit holes in it.

In heavy infestations there may be circular holes in the wood surface even smaller than the adult exit holes. This indicates that small wasps which are parasitic on the beetle larvae have also emerged.

POTENTIAL FOR DESTRUCTION

The amount of damage that an infestation of lyctid powderpost beetles can inflict is based on several factors.

The extent of infestation and subsequent damage is proportional to the starch content of the sapwood. Since heartwood is practically free of starch, it is immune.

The width of the sapwood portion of a given piece of wood will, within the limitations of the starch content, determine how much of the wood might ultimately be destroyed.

The diameter of the pores or vessels in the wood can also be a limiting factor. If they are not large enough to allow the female to insert the eggs, no infestation is likely to result. Several common lyctid species have structures for inserting eggs (ovipositors) that range from 0.076 to 0.083 mm in diameter. Hardwoods with pores having diameters greater than these are subject to attack. If the wood has had any type of coating or finish applied which closes the pores, it is not likely to be infested or reinfested. Softwoods do not have pores and usually have a low starch content, so they are essentially immune to infestation.

ROUND-HEADED BORERS

The round-headed borers belong to the family Cerambycidae, one of the largest and most important families of wood-boring beetles. More than 1,200 species have been recorded in the United States.

The larvae of all but a few members of the family live as borers in the tissues of trees and other woody plants. Species that feed under the bark of living trees may weaken and kill them, or cause defects and stains which seriously degrade lumber values. Species that attack recently felled trees, logs, or seasoned lumber also cause heavy losses.

FAMILY CHARACTERISTICS

The adults vary considerably in length: those encountered in seasoned wood from about 1/3 inch (8 mm) up to 2 inches (50 mm) or more. They are elongate, and usually more or less cylindrical in cross-section (some are flattened). The antennae are long, sometimes much longer than the body, giving rise to the common name "long-horned beetles." The

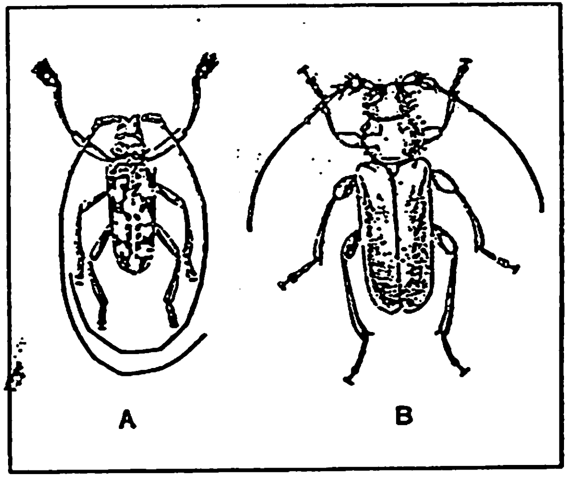


FIGURE 3-8: A. A typical sawyer. Several similar species attack coniferous wood in most parts of the country. B. The black-horned pine beetle, a blue-black species found on the West Coast. Similar species are found in other regions. Another common species, the newhouse borer of the western states, is slightly more slender and black in color. "A" and "B" from Forest Insects by R. W. Doane et al. Copyright 1936 by McGraw-Hill Book Company. Used with permission of McGraw-Hill Book Company.

coloration of those attacking softwoods is often rather drab and unattractive (Fig. 3-8 A and B). Some species attacking hardwoods are brightly colored and conspicuously marked.

The larvae are thin-skinned and whitish to cream-colored. They are long and narrow and very markedly segmented (Fig. 3-10B). They have been described as resembling the corrugated hose of a gas mask. The front part of the body is never abruptly and conspicuously larger than the rest and they are straight, never C-shaped like the powder-post beetle larvae. When full grown, they vary in length, according to the size of the adult, from 3/8 inch (9 mm) to over 2 inches (50 mm). The head is usually partly withdrawn into the first thoracic segment and is inconspicuous except for the dark brown jaws. Many of the larvae are legless, but some have three pairs of very tiny legs on the three segments of the thorax.

■ DISTRIBUTION AND ECONOMIC IMPORTANCE

Species in this family are in all of the states and in all of the U.S. territories. It is important to understand, however, that they are not all of economic importance, nor are representatives found attacking wood in houses in all of these areas.

The actual economic losses to wood caused by round-headed borers is probably greater from the downgrading of hardwood lumber than from these borers' attack on softwoods. Very often their attack on framing lumber is of little importance and does not restrict its use to a great extent. This is related to the fact that most species cease their attack on wood after it is seasoned and do not usually cause enough damage during their development in the wood to render it structurally weak. Borer-damaged wood quite often is classified as utility grade and is used with no problems.

The evidence of the past beetle attack remains in the wood and must be identified as such when structural timbers are inspected. There are some species which begin their development in dying trees, logs or unseasoned lumber (particularly if the unseasoned lumber has any bark edges left on it) and are able to complete their development as the wood seasons. The adults of these borers will emerge from the wood after it has been incorporated into a structure. They will not reinfest the wood because of its dryness, but they are of great concern to property owners who find them or evidence of their activity. It is not uncommon for the adults of various species to emerge from firewood logs brought indoors. Sighting of these adults can lead to a false impression of structural attack.

One of the most common sources of non-reinfesting round-headed borers in structural timbers is lumber sawn from fire-, disease-, or insect-killed trees. Very often the salvaging of such trees cannot proceed rapidly enough to prevent the invasion and partial development of round-headed borers. If this wood is not kiln-dried, the beetles can be distributed to any location where the wood is shipped for consumption. Because kiln-drying reduces the weight of wood, any that is to be shipped long distances is usually dried and thus rendered free of insects.

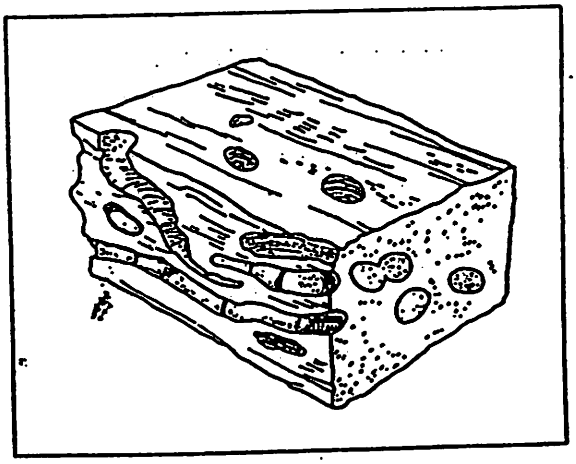


FIGURE 3-9. Round-headed borer damage. From Certification Training Manual for Structural Pesticide Applicators edited by R. Kaae and E. D. Young, Kellogg West, Center for Continuing Education, California State Polytechnic University, 1975. Used with permission.

■ GENERAL BIOLOGY AND HABITS OF FAMILY

The eggs are laid singly or in small groups on or in the bark during the spring, summer, or early fall. The eggs hatch within a few days, and the larvae begin feeding in the wood. Many species feed extensively directly under the bark before descending into the sapwood and, in some cases, the heartwood. The larval stage may last from a few months to several years. It is always prolonged if the wood has been cut into dimension lumber, which dries more rapidly. The pupal stage is passed in a cell near the surface, and the adult chews its way straight out of the wood.

The time of emergence varies with different species. It can occur outdoors any time from early spring to fall. Indoors, the climatic conditions are so different that emergence might occur at almost any season. Outdoors, the adults would mate, lay eggs, and die. Indoors, there are only two species that can reinfest dry, seasoned wood. They will be discussed separately and in more detail.

■ SIGNS OF INFESTATION

When long-horned beetles emerge from wood, they make slightly oval to nearly round exit holes (Fig. 3-9). If the points of exit are covered by building components, long-horned beetles will cut through such materials as plasterboard, hardboard, hardwood flooring, insulation, roofing felt and shingles, plywood, etc.

The size and shape of the holes varies with the species: they can be from 1/8 inch (3 mm) to as much as 3/8 inch (9 mm) or more in diameter. The sawyers (Fig. 3-8A) make almost circular holes from about 1/4 inch to 5/16 inch (6 to 7.5 mm) in diamater. The species of more flattened cross-section, such as the black-horned pine borer (Fig. 3-8B) and the new-house borer, make oval holes about twice as wide as high, the widest diameter being about 1/4 inch (6 mm). In some cases, there is coarse, even stringy, frass in evidence inside or around the exit holes.

Very often, the infestation is not active in structural timbers: the only evidence of infestation is the galleries which have been cut through when the wood was sawed and planed. Because they may have been cut at oblique angle, some of the galleries may appear to be quite elongate-oval in cross section. Some may have been sawed lengthwise. The diameter in true cross-section will vary with the age of the larva that made the gallery and with the species involved. Some of the larger ones are nearly 1/2 inch (13 mm) across. Tightly packed, rather coarse frass may be present in the exposed galleries. At other times the galleries are free of frass because it was loosely packed and has fallen free of the wood.

■ CHARACTERISTICS OF WOOD DAMAGED BY NON-REINFESTING ROUND-HEADED BORERS

The damage is known in the lumber trade as "worm holes." The galleries wind irregularly from directly below the bark into the sapwood. Many common species attacking softwoods feed primarily in the outer sapwood, and damage is not severe. The frass produced by the larvae is packed into the galleries once the feeding has proceeded below the wood surface. If bark edges have been left on lumber, there often is much frass in evidence underneath. The texture of the frass varies from rather fine and meal-like in some species to very coarse and almost excelsior-like in other species. Figure 3-9 shows the sort of damage that is typical.

■ POTENTIAL FOR DESTRUCTION

The amount of damage that can be expected from non-reinfesting round-headed borers is usually not significant. Most of the damage occurs before the wood is sawn and ceases almost immediately when the wood dries. Several common species that often infest wood being salvaged from fire- or insect-killed trees do survive the processing of the wood and will continue to develop for a year or more after the wood has been utilized.

The amount of structural damage that they inflict during this time is not enough to require any treatment. The major problem that they cause is the production of exit holes when they