Lethal Effects of Electrical Shock Treatments to the Western Drywood Termite (Isoptera: Kalotermitidae) and Resulting Damage to Wooden Test Boards

by

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ABSTRACT

Lethal effects of electrical shock treatments on the western drywood termite, *Incisitermes minor* (Hagen), were evaluated in artificially and naturally infested boards. Dimensional size of artificially infested boards used included 1 x 4, 2 x 4, and 4 x 6. Each artificially infested board contained 75 drywood termite workers, 25 each in three separate routed galleries. Sixty–six artificially infested boards were prepared and treated with electrical shock. Treatment of boards included waving the electrically emitting end over wooden surfaces or drilling small holes for placement of conductive wires. All artificially infested boards were opened and counts of live and dead termites made 3 days and 4 weeks after treatment. Untreated artificially infested boards were also included. Eighteen naturally infested boards were also treated during the study. Naturally infested boards were dissected 4 weeks after treatment and live and dead termites counted. Two separate tests using different treatment conditions were evaluated. The difference in the conditions between the two tests was the proximity of test boards to wire mesh contained in exterior stucco walls of the test structure. Study results revealed no statistically significant difference in termite mortality for galleries closest to or farthest from walls containing wire mesh. However, among artificially infested boards statistically significant differences did exist in treatment time and the number of holes to accommodate conductive wires. Excessive treatments with electrical shock and drilling for conductive wire placement resulted in scorched wood or holes in 70% of boards. Scorched boards and galleries suggest the mode-of-action of electrical shock to be the build up of excessive heat within termites and wood.

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INTRODUCTION

Localized treatment for the western drywood termite, *Incisitermes minor* (Hagen), has been the dominant method of control since the 1930s. The earliest published reports were for the use of spot applications of chemicals: arsenic–containing dusts, liquids, and fumigants (Randall *et al.* 1934). Newer, less toxic chemicals have also been tested and found to have promise (Scheffrahn *et al.* 1997). Non–chemical methods are also commercially available (Lewis & Haverty 1996, Lewis 1997, Lewis *et al.* 2000). One of the oldest commercially offered Non–chemical method of drywood termite control is electrical shock (Lewis 1997).

There are few reports on the lethal effects of electrical shock for drywood termites. Ebeling (1983) used the Electrogun (Etex, Ltd., Las Vegas, NV) to treat blocks of wood artificially infested with nymphs of *I. minor*. He described the mode of action as sparks jumping from termite to termite after short bursts of electricity were applied near galleries within wood. When passing the device over the surface of artificially infested wood for one minute, many termites initially survived (Ebeling 1983). However, delayed mortality was reported and attributed to the destruction of intestinal protozoa. Also reported in the same paper were empirical observations on the efficacy of electrocution after routine commercial treatments. Mortality from treatment was 74% immediately after treatment, 81.3% after 26 days, and 96.3% after 57 days. Efficacy information was also presented for 35 termite colonies treated with electrocution by pest control operators. The measure of efficacy was the appearance of new fecal pellets. During the duration of the study three of the 35 colonies required retreatment.

Lewis and Haverty (1996) also reported on the use of electrocution in controlling *I. minor* in artificially and naturally infested boards. Two tests were conducted, both by the same commercial vendor (Etex, Ltd., Las Vegas, NV). In the first test mortality did not exceed 89% 4 weeks after treatment in either artificially or naturally infested boards (Lewis and Haverty 1996). Most treated boards (56 of 57) contained live termites. However, Etex, Ltd., disputed the reduced mortality results as biased because the boards were too close to wire mesh in the stucco exterior walls of the test structure.

A second test was conducted using fewer boards (n = 18) in locations farther away from stucco exterior walls and sources of metal in the test structure. Mortality during the second test increased to 93% for artificially and naturally infested boards. However, the amount of time and number of holes drilled holes for the second test was at least two fold greater compared to the first test [Test 1 ($\bar{x}$± SD), 6.9 ± 5.6min and 6.5±5.0 holes versus Test 2, 27.0± 21.7min and 13.1±6.8 holes] (Lewis & Haverty 1996). Although efficacy results were reported in the aforementioned study, neither mortality nor survivorship by termite caste, or details on damage to test boards was included. Here we report details on proportions of survivors by caste and damage to test boards from high voltage and drilling.

MATERIALS AND METHODS

Rearing Chambers

Naturally infested wood from homes, decks, and fences were the sources of *I. minor* for laboratory colonies and naturally infested boards. Termites were removed from wood by placing cut sections in Berlese funnels (Borror *et al.* 1989) or by dissection. Termites removed by either collection technique were placed into rearing chambers made from birch tongue depressor (Bess & Ota 1960). Rearing chambers were stored in clear plastic boxes and held in an enclosed cabinet in a glass greenhouse at ambient environmental conditions for two to four weeks before use. We selected pseudergates of at least the 4^{th} instar; nymphs were used occasionally.

Test Building

The test building was 6.1 x 6.1m (37.2m^2; 154m^3) and contained four symmetrically built walls (Lewis & Haverty 1996). The building interior consisted of three levels; attic, drywall with 30cm x 235cm wall voids, and subarea. No pressure treated or otherwise chemically treated wood was used; foundation grade redwood was used for foundation sill plates. The exterior consisted of stucco walls and a composite shingled roof. Wooden panels with a door and two windows were centered on each wall and the entire assembly was detachable. There were no interior walls, insulation, or fire blocking. The foundation consisted of slab and raised perimeter.

Preparation of Artificially Infested Boards

Kiln–dried, vertical grain, and clear Douglas fir 1 x 4s, 2 x 4s, and 4 x 6s (cross–sectional dimensions of 1.8 x 8.7, 3.8 x 8.7, and 8.5 x 13.7cm, respectively) were cut into 61cm lengths. Each board consisted of four pieces made from three longitudinal cuts (Fig. 1). Three gallery spaces were routed into each board. Seventy–five drywood termites were placed within each board, 25 per gallery. Boards with termites

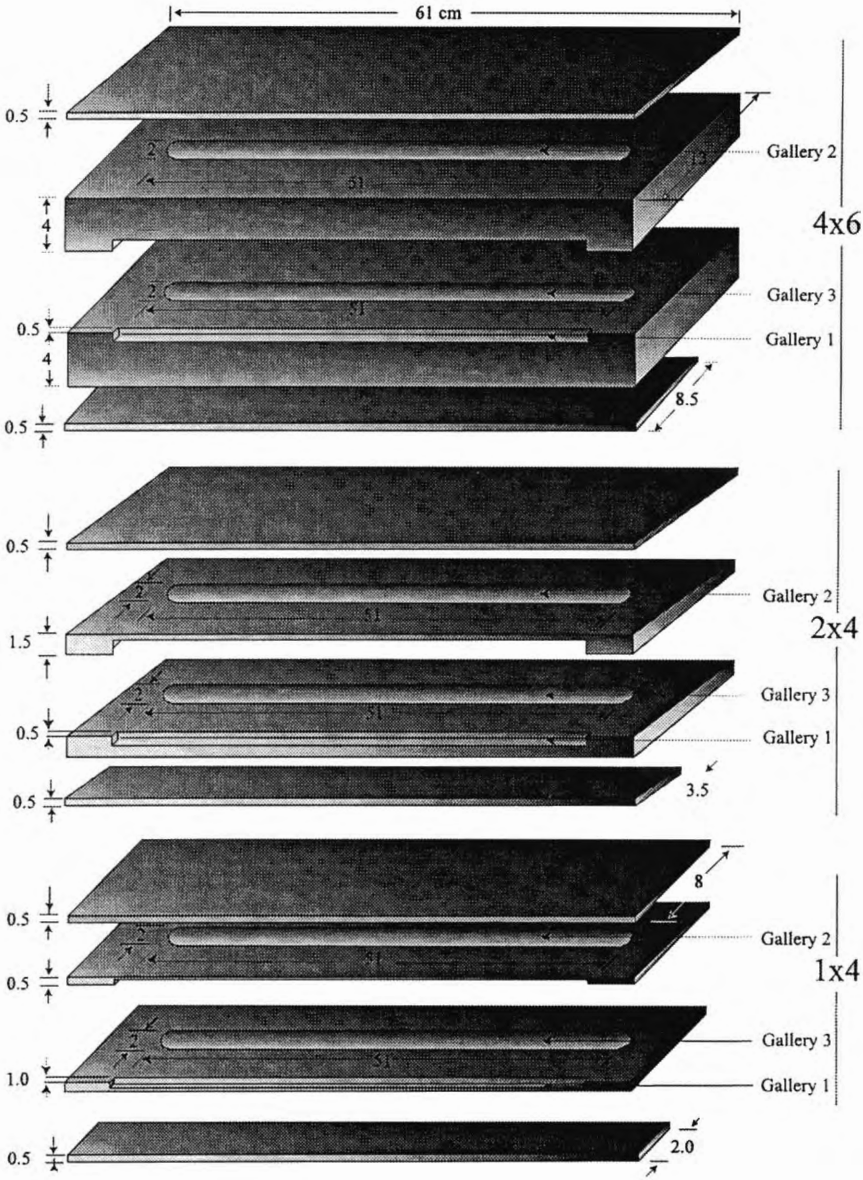

Fig. 1. Dissembled views of 1 x 4, 2 x 4, and 4 x 6 Douglas fir test boards artificially infested with drywood termites. Routed gallery locations also included. All measurements are in centimeters. Drawing not to scale.

were held together with two pieces of 2cm wide masking tape. Before installation, boards were stored at ambient conditions in the laboratory for 24 hours. With the exception of untreated boards (controls), no individual board was used in more than one treatment or test.

Placement of Artificially Infested Boards in the Test Building

For the wall void location, four 1 x 4s, sixteen 2 x 4s, and four 4 x 6s were used. Test boards were placed randomly in 1 of 4 positions on wall studs; at the bottom of or in the middle of the right or left stud. The test boards positioned at the lower position rested on the bottom plate. The orientation of galleries within a wall void was also randomized. Gallery 1 along the narrow edge of boards (Fig. 1) had two possible positions when viewed straight on; facing towards or rotated 180 degrees from the installer. An additional twelve boards were installed in the attic and twelve in the subarea. These boards were also positioned randomly on studs or bottom plate. Gallery orientation was also randomized before installation. Treatment boards were installed in the test building 24 hours before testing. Untreated boards were left undisturbed in a separate building 30m from the test building. Each board was affixed to the studs with two 0.3cm diameter x 5.1cm long drywall screws.

Placement of Naturally Infested Boards in the Test Building

The naturally infested boards were field collected and varied in dimensional size (1 x 6, 1 x 8, 2 x 4, 2 x 8, and 4 x 4) and wood species [ponderosa pine, *Pinus ponderosa* (Engelm); redwood, *Sequoia sempervirens* (D. Don); and Douglas fir, *Pseudotsuga menziesii* (Carr.)]. The criteria used for selecting naturally infested boards for the study were standard dimensional lumber that fit in wall voids and acoustical emission (AE) readings of >10 counts/min in at least one monitored position. Scheffrahn *et al.* (1993) reported AE readings »10 counts/min represent 20 live termites. We stratified boards into low, medium, and high acoustical activity, with corresponding acoustical emission readings of 10, 30, or > 40 counts/min using a hand–held Wood–destroying Insect Detector® (DowAgroSciences, Indianapolis, IN). When possible, an equal number of boards within each category were installed in the three levels of the test building. In total, nine naturally infested boards were used per test. All naturally infested boards within an AE category and test position were selected randomly.

Electrical Shock Applications

A commercial vendor conducted all applications. The equipment used was commercially marketed as the Electrogun (Etex, Ltd., Las Vegas, NV), a device that kills drywood termites by emitting high frequency electricity (100 kHz), high voltage (90,000 V), but low current (»0.5 amp) (Anonymous 1991). Treatment applications represented standard procedures in the field and were agreed upon by the vendor and authors. For the first test, 48 artificially infested and 9 naturally infested boards were installed and treated.

For exposed 2 x 4s and smaller pieces of wood, the probe end of the device was placed against the wooden surface. For larger pieces of wood and wood concealed behind drywall, a drill–and–pin method was used (Fig. 2). Small holes (1.6mm diameter) were drilled through the drywall and into the wood, and »15.2 cm long straight copper wires were inserted through the holes into the termite galleries. Several consecutive drillings per hole were used to insure that the electrical current was delivered at various depths within the boards. For applications conducted in the test building, the vendor had knowledge of the exact location of all test boards. Treatments were not monitored.

For the second test, 18 artificially infested boards were installed in locations away from metal or concrete. Six artificially infested boards each were installed in the attic, drywall voids, and subarea. All boards and gallery positions were randomized. The vendor was asked to treat the boards as before. Naturally infested boards were similarly installed for this second test. Nine naturally infested boards were installed: three each in the attic, wall void, and subarea. These boards were also randomized prior to installation and treatment.

Assessment of Treatment Efficacy

The day following treatment, all artificially infested boards were removed from the test building and stored in the laboratory until 3 days after treatment. The boards were then opened and live and dead termites counted. Live termites were placed in tongue depressor rearing chambers. Percent mortality was determined 4 weeks after treatment. Termites crushed by handling were excluded for analysis. Untreated boards were assessed in the same manner.

Naturally infested boards were removed from the test building and stored in a glass greenhouse. Four weeks after treatment, boards were cut into small lengths (»10 cm) and carefully dissected. Live and dead termites were counted and sorted by caste.

Statistical Analysis

For each artificially infested board, percent mortality was calculated by combining data for all galleries. Separate records were kept for each gallery for artificially infested boards. An unfortunate complication resulted from the drill–and–pin method for using electrocution. Holes were left in the boards, occasionally allowing termites to escape. If the total number of termites remaining in an individual artificially infested board was <48, data for that board were discarded for analysis. Because we had little control over the number of termites in a naturally infested board, we calculated percent mortality using all live and dead termites dissected and removed from the board.

Summary statistics for mortality levels ($\bar{x}$ ± SD) among days post-treatment, test building location, board dimension, and caste proportions were derived with the MEAN procedure (PROC MEAN, SAS Institute 1994). Differences in percent mortality in galleries for boards near or away from sources of metal were analyzed using Tukey's Studentized Range Test (PROC GLM, SAS Institute 1994). All artificially infested boards were visually inspected after treatment for signs of damage, drilled holes, and burn marks. Differences in the number of drilled holes between the two electrocution tests for artificially infested boards were analyzed using the Kruskal-Wallis Test (Chi–square approximation) (PROC NPAR1WAY, SAS Institute 1994). Differences in the number of drilled holes between the two electrocution tests for naturally infested boards were analyzed using a two–sample *t*–test (PROC TTEST, SAS Institute 1994).

RESULTS AND DISCUSSION

Artificially Infested Boards

Results of the first electrocution test revealed 3 day mortality to be low for all board sizes treated for all locations in the test building. The drywall level was the only location were mortality exceeded 50% (Table 1). Surviving termites were found in all 48 boards (Table 1 & 2). For one 2 x 4 board treated in the attic, all termites survived (Table 2). Interestingly, the lowest mortality level was found in the attic, the most accessible and easiest location to treat in the test building. At 4 weeks,

Table 1. Percent mortality ($\bar{x}$ ± SD) of dry wood termites in artificially infested boards of three different dimensional sizes 3 days after in situ treatment with electrocution in the first test.

Lumber Dimension	Attic n[a]	Attic $\bar{x}$	Attic SD	Attic Boards live[b]	Dry Wall n[a]	Dry Wall $\bar{x}$	Dry Wall SD	Dry Wall Boards live[b]	Subarea n[a]	Subarea $\bar{x}$	Subarea SD	Subarea Boards live[b]
1x4	2	21.9	1.1	2	4	53.5	14.9	4	2	30.9	12.2	2
2x4	8	27.6	21.0	8	16	52.2	18.4	16	8	41.9	20.5	8
4x6	2	23.1	23.0	2	4	62.6	21.1	4	2	46.6	45.4	2

[a]n = the number of boards for each dimensional size treated in the test structure.
[b]Number of boards with live termites 3 days after treatment.

Table 2. Percent mortality of drywood termites in artificially infested boards in each of three locations 3 days after *in situ* treatment with electrocution in the first test.

Lumber Dimension	Location	No. Alive	No. Dead	Percent Mortality
1x4	Attic	56	15	21.1
1x4	Attic	58	17	22.7
2x4	Attic	59	16	21.3
2x4	Attic	37	38	50.7
2x4	Attic	59	17	22.4
2x4	Attic	30	41	57.7
2x4	Attic	65	10	13.3
2x4	Attic	34	32	48.5
2x4	Attic	77	0	0
2x4	Attic	6	27	10.1
4x6	Attic	68	7	9.3
4x6	Attic	43	30	41.1
1x4	Wall	28	41	59.4
1x4	Wall	42	33	44.0
1x4	Wall	39	26	40.0
1x4	Wall	21	53	71.6
2x4	Wall	41	19	31.7
2x4	Wall	31	39	55.7
2x4	Wall	25	28	52.8
2x4	Wall	51	22	30.1
2x4	Wall	37	31	45.6
2x4	Wall	55	20	26.7
2x4	Wall	36	39	52.0
2x4	Wall	29	43	59.7
2x4	Wall	2	46	95.8
2x4	Wall	37	35	48.6
2x4	Wall	48	26	35.1
2x4	Wall	10	61	85.9
2x4	Wall	31	41	56.9
2x4	Wall	31	37	54.4
2x4	Wall	47	26	35.6
2x4	Wall	28	47	62.7
4x6	Wall	32	41	56.2
4x6	Wall	44	30	40.5
4x6	Wall	5	58	92.1
1x4	Subarea	56	16	22.2
1x4	Subarea	23	15	39.5
2x4	Subarea	40	27	40.3
2x4	Subarea	43	31	41.9
2x4	Subarea	50	24	32.4
2x4	Subarea	10	21	67.7
2x4	Subarea	59	12	16.9
2x4	Subarea	37	32	46.4
2x4	Subarea	59	14	19.2

Table 2. Continued

Lumber Dimension	Location	No. Alive	No. Dead	Percent Mortality
2x4	Subarea	19	53	73.6
4x6	Subarea	65	11	14.5
4x6	Subarea	10	57	85.1
Totals		1,899	1,426	42.9[a]
Attic $\bar{x}$ Mortality			$\bar{x}$ = 25.9	SD = 18.3[b]
Wall $\bar{x}$ Mortality			$\bar{x}$ = 54.1	SD = 26.7[c]
Subarea $\bar{x}$ Mortality			$\bar{x}$ = 40.8	SD = 22.3[b]
Entire Structure $\bar{x}$ Mortality			$\bar{x}$ = 43.7	SD = 22.1[d]

[a]Overall percent mortality is based on the sum of the live and dead termites for 48 treated boards. Missing individuals were excluded from analysis.
[b]Attic and subarea $\bar{x}$ ± SD is based on individual percent mortality values for 12 treated boards.
[c]Wall $\bar{x}$ ± SD is based on individual percent mortality values for 48 treated boards.

mortality increased and exceeded 80% for most building locations and individual boards (Table 3 & 4). From the results it appeared that most treated boards and locations within the test structure had at least a two fold increase in mortality over the 28 day period. However, untreated boards (controls) also had a twofold increase in mortality: 12.7 ± 14.7% at 3 day and 33.5 ±16.8 % at 4 weeks (Lewis & Haverty 1996). This suggests that handling or our rearing method was the source of increased mortality not delayed mortality from electrical shock. Although the average mortality during the first test for the entire structure was 80.6%, this value did not meet or exceed the 90% minimum value for efficacy and, therefore, was deemed an ineffective drywood termite treatment method (Lewis & Haverty 1996).

Table 3. Percent mortality ($\bar{x}$ ± SD) of drywood termites in artificially infested boards of three different dimensional sizes 4 weeks *in situ* treatment with electrocution in the first test.

	Attic				Dry Wall				Subarea			
Lumber Dimension	n^a	$\bar{x}$	SD	Boards live[b]	n^a	$\bar{x}$	SD	Boards live[b]	n^a	$\bar{x}$	SD	Boards live[b]
1x4	2	87.0	0.46	2	4	98.3	3.3	1	2	64.9	2.5	2
2x4	8	70.6	21.8	8	16	81.9	10.7	15	8	81.0	16.8	6
4x6	2	82.1	15.4	2	4	84.8	10.5	3	2	86.2	19.5	1

[a]n = the number of boards for each dimensional size treated in the test structure.
[b]Number of boards with live termites 4 weeks after treatment.

Table 4. Percent mortality of drywood termites in artificially infested boards in each of three location 4 weeks after *in situ* treatment with electrocution in the first test.

Location Dimension	Location	No. Alive	No. Dead	Percent Mortality
1x4	Attic	9	12	87.3
1x4	Attic	12	3	84.0
2x4	Attic	36	6	52.0
2x4	Attic	1	0	98.6
2x4	Attic	25	4	64.1
2x4	Attic	2	2	97.2
2x4	Attic	45	6	40.0
2x4	Attic	6	6	90.9
2x4	Attic	64	15	55.8
2x4	Attic	27	4	60.9
4x6	Attic	21	4	72.0
4x6	Attic	8	4	89.0
1x4	Wall	0	1	100
1x4	Wall	3	3	95.7
1x4	Wall	0	0	100
1x4	Wall	0	0	100
2x4	Wall	2	1	96.7
2x4	Wall	20	2	71.4
2x4	Wall	15	4	78.9
2x4	Wall	2	0	96.2
2x4	Wall	4	2	94.5
2x4	Wall	19	4	72.1
2x4	Wall	5	4	93.3
2x4	Wall	12	5	84.0
2x4	Wall	3	5	95.8
2x4	Wall	0	0	100
2x4	Wall	9	3	87.5
2x4	Wall	10	4	86.5
2x4	Wall	2	0	97.2
2x4	Wall	14	1	80.6
2x4	Wall	16	4	78.1
4x6	Wall	18	2	76.0
4x6	Wall	14	3	80.8
4x6	Wall	13	3	82.4
4x6	Wall	0	0	100
1x4	Subarea	24	7	66.7
1x4	Subarea	14	1	63.2
2x4	Subarea	16	5	76.1
2x4	Subarea	4	5	94.6
2x4	Subarea	29	3	60.8
2x4	Subarea	0	0	100
2x4	Subarea	25	9	64.8
2x4	Subarea	10	5	85.5
2x4	Subarea	30	6	58.9
2x4	Subarea	0	2	100

Table 4 continued.

Location Dimension	Location	No. Alive	No. Dead	Percent Mortality
4x6	Subarea	24	8	68.4
4x6	Subarea	0	0	100
Totals		593	1,599	72.9[a]
Attic $\bar{x}$ Mortality			$\bar{x}$ = 70.1	SD = 19.7[b]
Wall $\bar{x}$ Mortality			$\bar{x}$ = 83.2	SD = 12.3[c]
Subarea $\bar{x}$ Mortality			$\bar{x}$ = 75.1	SD = 18.7[b]
Entire Structure $\bar{x}$ Mortality			$\bar{x}$ = 77.8	SD = 16.8[d]

[a]Overall percent mortality is based on sum of the live and dead termites for 48 treated boards. Missing individuals were excluded from analysis.
[b]Attic and subarea $\bar{x} \pm$ SD is based on individual percent mortality values for 12 treated boards.
[c]Walls $\bar{x} \pm$ SD is based on individual percent mortality values for 24 treated boards.
[d]Entire structure $\bar{x} \pm$ SD is based on individual percent mortality values for 48 treated boards.

Results for artificially infested boards from the second electrocution test were much improved over the first. Still half of the treated boards (9 of 18) had survivors (Table 5); albeit, only four boards had 12 survivors or more. Overall mortality for Test 2 exceeded 93% after 3 days. Four weeks after treatment, only three boards had survivors (Table 6), and the mean mortality for the entire test exceeded 98%.

Naturally Infested Boards

Mortality of termites in the naturally infested boards was similar for both electrocution tests. Mortality in the first test was 88.6% compared to 95.0% for the second test (Table 7). The number of boards with survivors was also similar between tests: 8 boards in the first versus 5 boards in the second. However, there were 40% more termites in the second test compared to the first test: 5,838 versus 3,740.

Several of the naturally infested boards treated during Test 2 might have caused a reinfestation of the building had the electrocution treatment been done in an actual use situation. Thirty-five alates, 254 pseudergates, and one soldier survived treatment and were dissected from three naturally infested boards (Table 8). The surviving alates and pseudergates signify treatment failures. Drywood termite colony growth is slow taking as long as 5 years to reach »500 individuals (Harvey 1934a, b), however, the presence of live alates and pseudergates capable of becoming reproductives provide potential for a continuing infestation. Cabrera & Rust (1994) also reported considerable survival (33%) for pseudergates eight months after their removal from natural

Table 5. Percent Mortality of drywood termites in artificially infested boards in each of three locations 3 days after *in situ* treatment with electrocution in the second test.

Location Dimension	Location	No. Alive	No. Dead	Percent Mortality
1x4	Attic	0	77	100.0
2x4	Attic	0	75	100.0
2x4	Attic	0	78	100.0
2x4	Attic	0	75	100.0
2x4	Attic	1	74	98.7
4x6	Attic	0	76	100.0
1x4	Wall	17	55	76.4
2x4	Wall	25	45	64.3
2x4	Wall	3	69	95.8
2x4	Wall	4	71	94.7
2x4	Wall	1	70	98.6
4x6	Wall	12	62	83.8
1x4	Subarea	0	72	100.0
2x4	Subarea	0	76	100.0
2x4	Subarea	0	74	100.0
2x4	Subarea	0	74	100.0
2x4	Subarea	3	71	95.9
4x6	Subarea	16	45	73.8
Totals		82	1,239	93.8[a]
Attic $\bar{x}$ Mortality			$\bar{x}$ = 99.8[b]	SD = 0.53[b]
Wall $\bar{x}$ Mortality			$\bar{x}$ = 85.6[b]	SD = 13.4[b]
Subarea $\bar{x}$ Mortality			$\bar{x}$ = 95.0[b]	SD = 10.5[b]
Entire Structure $\bar{x}$ Mortality			$\bar{x}$ = 93.4	SD = 11.4[c]

[a]Overall percent mortality is based on sum of the live and dead termites for 18 treated boards. Missing individuals were excluded from analysis.
[b]Attic, wall and subarea $\bar{x} \pm$ SD is based on individual percent mortality values for 6 treated boards.
[c]Entire structure $\bar{x} \pm$ SD is based on individual percent mortality values for 18 treated boards.

colonies. The large number of surviving alates in our study could be explained by their ability to tolerate greater extreme temperatures compared to pseudergate workers (Rust & Reierson 1997). As few as 20 surviving pseudergate workers can lead to the production of new reproductives and colony survival (Lewis 1997). Reviewing survival of different castes for both tests, it appears that 7 of the 18 treated boards would continue to be infested and could lead to reinfestation of additional locations in the building. For comparison, the caste proportions for untreated naturally infested boards is included (Table 9).

There is an obvious discrepancy between the results reported in the two tests. Yes, mortality increased in the second test, although the reason for the increased mortality was not proximity to sources of metal.

Table 6. Percent mortality of dry wood termites in artificially infested boards in each of three locations 4 weeks after *in situ* treatment with electrocution in the second test.

Location Dimension	Location	No. Alive	No. Dead	Percent Mortality
1x4	Attic	0	77	100.0
2x4	Attic	0	75	100.0
2x4	Attic	0	78	100.0
2x4	Attic	0	75	100.0
2x4	Attic	0	74	100.0
4x6	Attic	0	76	100.0
1x4	Wall	9	63	87.5
2x4	Wall	8	62	88.6
2x4	Wall	0	72	100.0
2x4	Wall	0	75	100.0
2x4	Wall	0	71	100.0
4x6	Wall	2	72	97.3
1x4	Subarea	0	72	100.0
2x4	Subarea	0	76	100.0
2x4	Subarea	0	74	100.0
2x4	Subarea	0	74	100.0
2x4	Subarea	0	74	100.0
4x6	Subarea	0	62	100.0
Totals		19	1,302	98.6[a]
Attic $\bar{x}$ Mortality			$\bar{x}$ = 100.0[b]	SD = ---[b]
Wall $\bar{x}$ Mortality			$\bar{x}$ = 95.6[b]	SD = 5.9[b]
Subarea $\bar{x}$ Mortality			$\bar{x}$ = 100.0[b]	SD = ---[b]
Entire Structure $\bar{x}$ Mortality			$\bar{x}$ = 98.5[d]	SD = 3.9[c]

[a]Overall percent mortality is based on sum of the live and dead termites for 18 treated boards. Missing individuals were excluded from analysis.
[b]Attic, wall, and subarea $\bar{x} \pm$ SD is based on individual percent mortality values for 6 treated boards.
[c]Entire sturcture $\bar{x} \pm$ SD is based on individual percent mortality values for 18 treated boards.

There was no significant difference in termite mortality (46.7 ± 20.8% versus 51.1 ± 19.2%, $F = 0.38$, df = 1, 31, $P > 0.54$) when Gallery 1 was oriented toward or away from wire mesh contained in exterior walls of the test building. However, there was almost a twofold difference between Test 1 and Test 2 in number of holes drilled in the artificially infested boards (Table 10) and Lewis & Haverty (1996). Combining the results of both tests we infer that drilling with use of current–conducting metal and a 4–fold increase in treatment time explain the increase in mortality between the two tests. Advance knowledge of board and gallery position, along with visual signs of damage and fecal pellet kick out holes, also guaranteed correct wire placement and high termite mortality.

Table 7. Percent mortality of drywood termites in naturally infested boards of various dimensions 4 weeks after *in situ* treatment with electrocution.

Lumber Dimension	Board Length (cm)	Test Location	No. Alive	No. Dead	Percent Mortality
		Test 1			
1x8	175.3	Attic	16	390	96.1
1x8	152.4	Attic	2	696	99.7
4x4	66.0	Attic	41	184	81.8
1x8	213.4	Wall	12	200	94.3
1x8	301.0	Wall	192	452	70.2
2x4	236.2	Wall	6	678	99.2
1x8	149.9	Subarea	0	298	100.0
1x8	111.8	Subarea	3	221	98.7
2x4	142.2	Subarea	280	372	57.1
Overall Total			549	3.191	85.3[a]
$\bar{x}$ Mortality				$\bar{x}$ = 88.6[b]	SD = 15.5[b]
		Test 2			
1x8	119.4	Attic	0	210	100.0
2x4	57.2	Attic	0	0	----[c]
2x8	56.8	Attic	62	2,222	97.3
2x4	191.8	Wall	41	252	86.0
2x4	190.5	Wall	0	95	100.0
4x4	172.7	Wall	165	1,687	91.1
1x6	76.2	Subarea	20	1,071	98.2
1x8	143.5	Subarea	0	5	100.0
2x4	125.7	Subarea	1	7	88.0
Overall Total			289	5,549	95.1[a]
$\bar{x}$ Mortality				$\bar{x}$ = 95.0[b]	SD = 5.8[b]
Overall Percent Mortality			838	8,740	91.2[d]

[a]Test 1 and Test 2 overall total are based on the sum of the live and dead termites for 9 treated boards.
[b]$\bar{x} \pm$ SD for Test 1 and Test 2 are based on individual percent mortality values for 9 treated boards.
[c]Non–infested board, no live or dead termites recovered.
[d]Overall percent mortality based on the sum of the live and dead termites for 18 treated boards.

Damage to artificially and naturally infested boards was considerable during electrocution applications. For artificially infested boards, most were drilled; Test 1, 36 of 48 and Test 2, 18 of 18, respectively. Literally hundreds of holes were drilled. Individual boards had as many as 30 holes (Figs. 2 & 3). Drywall sheets also were damaged from drilling (Fig. 4). The most frequently drilled artificially infested board was the 4 x 6, because all boards in both tests were drilled (Table 10). Among artificially infested boards, the tendency was to drill more holes in larger

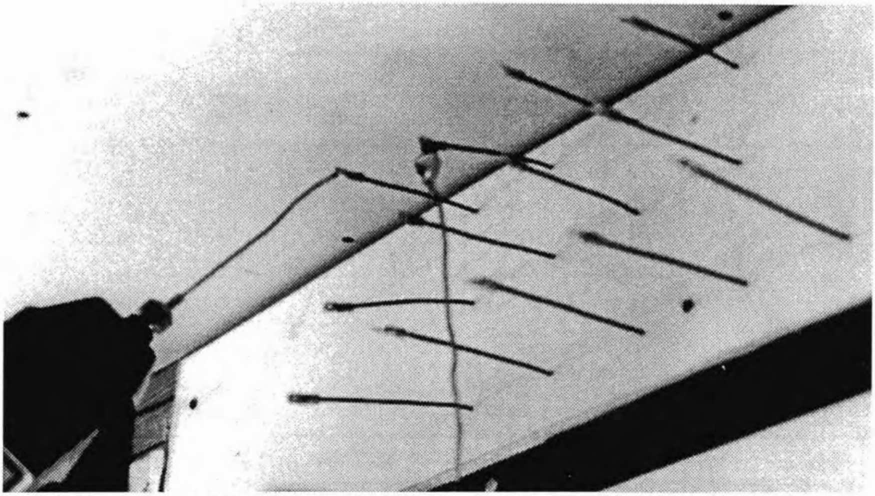

Fig. 2. Drill-and-pin application of electrical shock applied to naturally infested board (1 by 8, 3 m long) behind drywall in the test structure. Copper wires 1.6 mm diameter x 15.2 cm long were inserted into holes drilled into drywall sheets during the first electrocution test. Electrocution device is also shown in the foreground.

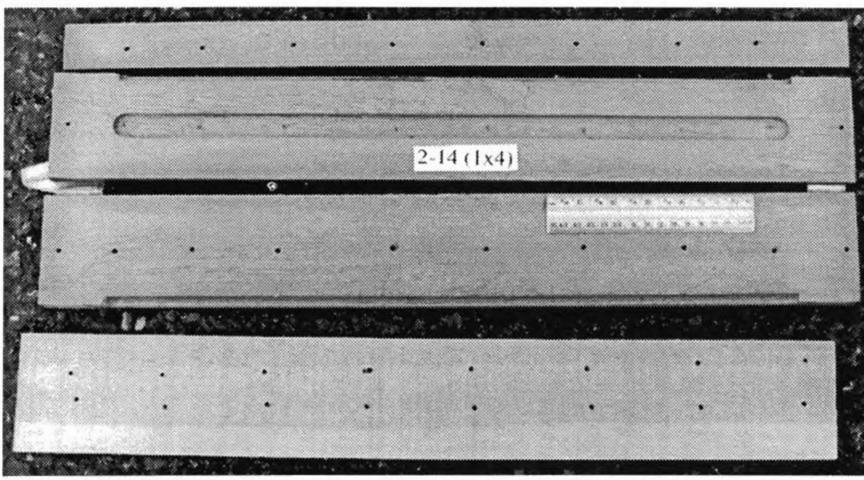

Fig. 3. Artificially infested test board (1 x 4) showing holes drilled for electrical shock treatment. Applications were conducted during the first test.

boards. The major difference between the two tests was increased drilling of gallery 2 during the second test. Gallery 2 was also the location for most survivors from Test 1 (Lewis & Haverty 1996). This increased drilling explains the twofold difference in mean number of holes drilled between Test 1 and 2 (6.5 versus 13.1) (Lewis & Haverty

Table 8. Number by caste and percentages of drywood termite pseudergates dissected from naturally infested boards of various dimensional sizes treated with electrocution.

Lumber Dimension	Board Length (cm)	Test Location	No. Alive P/S/AL[a]	No. Dead P/S/AL	Percent Pseudergates A/T[b]
		Test 1			
1x8	175.3	Attic	16/0/0	376/14/0	100/97
1x8	152.4	Attic	2/0/0	675/16/5	100/99
4x4	66.0	Attic	40/0/1	183/1/0	100/99
1x8	213.4	Wall	12/0/0	197/3/0	100/99
1x8	301.0	Wall	185/7/0	422/30/0	96/94
2x4	236.2	Wall	3/0/0 3	77/1/0	100/99
1x8	149.9	Subarea	0/0/0	293/5/0	0/99
1x8	111.8	Subarea	2/0/1	213/8/0	67/96
2x4	142.2	Subarea	273/7/0	338/33/1	98/94
Totals			533/14/2	3,704/111/6	97/96[b]
		Test 2			
1x8	119.4	Attic	0/0/0	203/5/2	0/97
2x4	57.2	Attic	0/0/0	0/0/0	----[c]
2x8	56.8	Attic	55/0/7	2,021/33/168	88/91
2x4	191.8	Wall	35/1/5	241/0/11	85/94
2x4	190.5	Wall	0/0/0	93/0/2	0/98
4x4	172.7	Wall	142/0/23	1329/1/357	86/79
1x5	76.2	Subarea	20/0/0	1,204/34/13	100/96
1x8	143.5	Subarea	0/0/0	4/1/0	0/80
2x4	125.7	Subarea	0/0/0	7/0/0	100/100
Totals			253/1/35	4,922/74/533	88/89[b]
Overall Totals			786/15/37	7,996/185/559	94/92[d]

[a]Castes represented include pseudergates (P), soldier (S), and alate (AL) both winged and dealate forms.
[b]First number (A) represents the percentage of pseudergates for the sum of all live termites. The second number (T) represents the percentage of pseudergates of the total of all live and dead termites.
[c]No live or dead termites were recovered from this uninfested board.
[d]Overall caste numbers and percentage pseudrgates for live and total termites for 18 boards treated with electrocution.

1996). The number of drilled holes for naturally infested boards was similar for both tests (Table 11). Data for burn marks was not recorded for naturally infested boards due to the difficulty in viewing boards (fencing and decking) that were discolored from years of exposure to outdoor weather conditions.

Burn marks on treated artificially infested boards also increased with

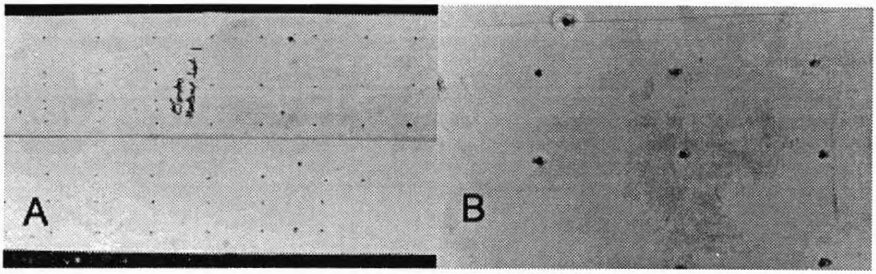

Figure 4. Wide-angle (A) and close-up view (B) of sheetrock sheet drilled with holes for electrical shock applications. Each piece of drywall is »1.5 m long. Note the number and pattern of holes.

Table 9. Number by caste and percentages of drywood termite pseudergates dissected from untreated, naturally infested boards of various dimensional sizes.

Lumber Dimension	Board Length (cm)	No.Alive P/S/AL[a]	No. Dead P/S/AL	Percent Pseudergate[b]
1x8	153.7	72/0/0	8/0/0	100
1x8	144.8	596/0/0	6/2/0	99
1x8	170.2	17/0/1	8/0/0	96
1x8	156.2	28/0/0	3/2/0	94
1x8	232.4	17/0/0	0/0/0	100
1x8	218.9	137/0/1	1/0/0	99
1x8	127.0	43/6/0	0/0/0	88
2x4	246.4	7/0/0	0/0/0	100
2x4	246.4	123/0/0	0/0/0	100
2x6	86.4	2,923/19/1	58/0/0	99
4x4	53.3	99/0/0	4/0/0	100
4x4	55.9	167/2/0	0/0/0	99
4x4	181.0	589/26/150	0/0/0	78
Caste numbers		4,816/53/153	88/4/0	96[c]

[a]Castes represented include pseudergate (P), soldier (S), and alate (AL), both winged and dealate forms.
[b]Live and dead termites are included in percent calculations.
[c]Sum of live and dead pseudergates for 13 untreated naturally infested boards were used in calculating percent pseudergates.

increased application time. Although the number of boards with burn marks was similar between tests, 15 and 14, less than half the number of boards were treated during Test 2 (Table 10). Burn marks appeared as serpentine lines on boards (Fig. 5). Burn marks on accessible surfaces were obvious. However, in concealed locations behind drywall and inaccessible areas, they probably would go unnoticed. It is not known what fire potential these burn marks pose to structures.

Table 10. Number of boards drilled, number of holes drilled/board ($\bar{x}$ ± SD and range), hole distribution by gallery, and number of boards with burn marks for artificially infested boards treated *in situ* with electrocution.

Lumber Dimension	n	No. boards drilled	Total Number of holes	Holes/board (X ± SD)	Holes/board (Range)	Hole distribution by gallery[a]	No. of boards w/ burn marks
				Test 1			
1x4	8	5	39	4.9 ± 5.0	0 – 10	17/5/15	2
2x4	32	23	197	6.2 ± 4.6	0 – 16	84/41/100	11
4x6	8	8	90	11.3 ± 5.9	5 – 19	13/0/19	2
Test 1 Totals	48	36	326	$\bar{x}$ = 6.8 ± 5.2[c]			
				Test 2			
1x4	3	3	24	8.0 ± 4.6	4 – 13	6/0/2[b]	3
2x4	12	12	172	14.3 ± 6.9	7 – 30	42/88/82	10
4x6	3	3	46	15.3 ± 3.2	13 – 19	14/13/17	1
Test 2 Totals	18	18	242	$\bar{x}$ = 13.4 ± 6.4[c]			

[a]Numbers represent holes by gallery (1,2, and 3). See Fig. 1 for gallery configuration within boards.
[b]Data for one 1x4 board excluded from analysis.
[c]Mean number of drill holes was significantly different between Test 1 and Test 2.

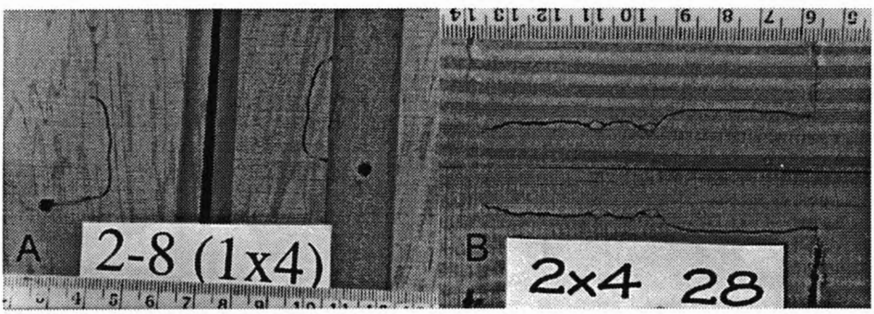

Fig. 5. Close-up view of 1 x 4 (A) and 2 x 4 (B) artificially infested boards treated by electrical shock. Note the number of drilled holes and burn marks.

After two tests of electrocution both on artificially and naturally infested boards containing drywood termites, we conclude that knowledge of where colonies are located and field experience in application are essential for treatment success. However, having this detailed information in homes from a single treatment visit may not be enough to guarantee success. Perhaps control service agreements with multiple

Table 11. Number of holes drilled in naturally infested boards of varying dimensional size and length treated *in situ* with electrocution.

Lumber Dimension	Board Length (cm)	Test Location	No. Holes
		Test 1	
1x8	175.3	Attic	0
1x8	152.4	Attic	0
4x4	66.0	Attic	18
1x8	213.4	Wall	87
1x8	301.0	Wall	93
2x4	236.2	Wall	28
1x8	149.9	Subarea	0
1x8	111.8	Subarea	0
2x4	142.2	Subarea	0
Test 1 ($\bar{x} \pm SD$)			25.1 ± 38.2[a]
		Test 2	
1x8	119.4	Attic	0
2x4	57.2	Attic	8
2x8	56.8	Attic	4
2x4	191.8	Wall	46
2x4	190.5	Wall	50
4x4	172.7	Wall	40
1x5	76.2	Subarea	0
1x8	143.5	Subarea	0
2x4	128.7	Subarea	0
Test 2 ($\bar{x} \pm SD$)			16.5 ± 21.9[a]

[a]The mean number of holes drilled was not significantly different between Test 1 and Test 2 ($t = 0.59$, $df = 16$, $P > 0.56$).

revisits could improve treatment success. This localized treatment method appears technique driven, labor intensive, and when using drill-and-pin methods and long treatment times, damaging to the structure treated.

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