

# TERMITE GALLERY CHARACTERIZATION in LIVING TREES USING DIGITAL RESISTOGRAPH TECHNOLOGY

Weste L.A. Osbrink and Alan R. Lax

United States Department of Agriculture, Agricultural Research Service, Southern Regional Research Center, 1100 Robert E. Lee Blvd. New Orleans, LA 70124, U.S.A

**Abstract** Characterization of populations of subterranean termites on a research facility in New Orleans, La., determined that a number of living trees were infested with the Formosan subterranean termite, *Coptotermes formosanus* Shiraki. The amount of internal tree damage was evaluated using a resistograph. The resistograph is functionally a cordless "smart" drill that transmits information to a computer regarding the mechanical properties of wood along the length of the drill hole. A rapid fall in drilling energy at a certain depth indicates the presence of a gallery. Plots of these data quantify the presence of termite galleries through detection of changes in tree density. Probing of a tree on different sides was critical for detection of termite galleries, which were generally not centrally located. Termite galleries were detected in 58.3% of the 12 infested trees as follows: 3 of 5, 2 of 4, and 2 of 3, bald cypress, live oak, and pine trees, respectively. Of the termite-infested trees, 33.0% were deemed likely to fail, specifically, 2 cypress and 2 pines. The resistograph is a viable tool for locating and quantifying internal structural loss of trees and causes minimal damage to the tree. Acquired information can be incorporated into a decision-making process regarding the structural integrity, safety, and the suitability of a tree for removal or drill and foam treatment.

**Key Words** *Coptotermes formosanus* *Reticulitermes* sp.

## INTRODUCTION

The Formosan subterranean termite, *Coptotermes formosanus* Shiraki, was introduced into the United States in the thousands of tons of wooden military cargo shipped back from the Asian theater following World War II (La Fage, 1985). New Orleans, Louisiana, was one of the most active ports of entry. Populations of Formosan termites flourished in the warm, humid climate of New Orleans, virtually blanketing the city over the last half century. *C. formosanus* commonly infests living urban trees in the greater New Orleans area (Osbrink et al., 1999). These infestations often remain undetected until the termite population becomes so great as to cause structural failure of the tree or external signs such as mudding become visible. Quantification of termite damage in living trees is an area that has been little studied. Understanding and detecting hidden termite populations in trees is critical because of the danger of falling trees, the aesthetic and historic importance of trees to the city, and to reduce the threat of termites moving into and destroying urban structures (Osbrink et al., 1999). Recently, technology for the detection and evaluation of incipient decay has been developed for use by arboriculturists (Bethge et al., 1996; Costello and Quarles, 1999; Dolwin et al., 1999). One such device is the resistograph. The resistograph is functionally a cordless "smart" drill that transmits information to a computer regarding the mechanical properties of wood along the length of the drill hole (Costello and Quarles, 1999; Dolwin et al., 1999). A rapid fall in the drilling energy required at a certain depth indicates the presence of a void. Plots of this data quantify the presence of voids through detection of changes in tree density. The objective of this research was to quantify galleries in living trees infested with subterranean termites at the Southern Regional Research Center in New Orleans, Louisiana, U.S.A.

## MATERIALS and METHODS

The Southern Regional Research Center (SRRC) occupies 141,645 m<sup>2</sup> and is located at the north east corner of City Park in New Orleans, Louisiana, U.S.A. Trees were identified to species and inspected for termites through visual inspection and by placing pine stakes (2 by 4 by 20 cm) on opposing sides of the base of a tree (Figure 1; Osbrink et al., 1999). Termite-infested trees were confirmed with a prototype acoustical listening device (Mankin et al., 2000). Each tree was evaluated for internal voids through drilling on one side at 4 heights (30.5, 61.0, 91.4, and 121.9

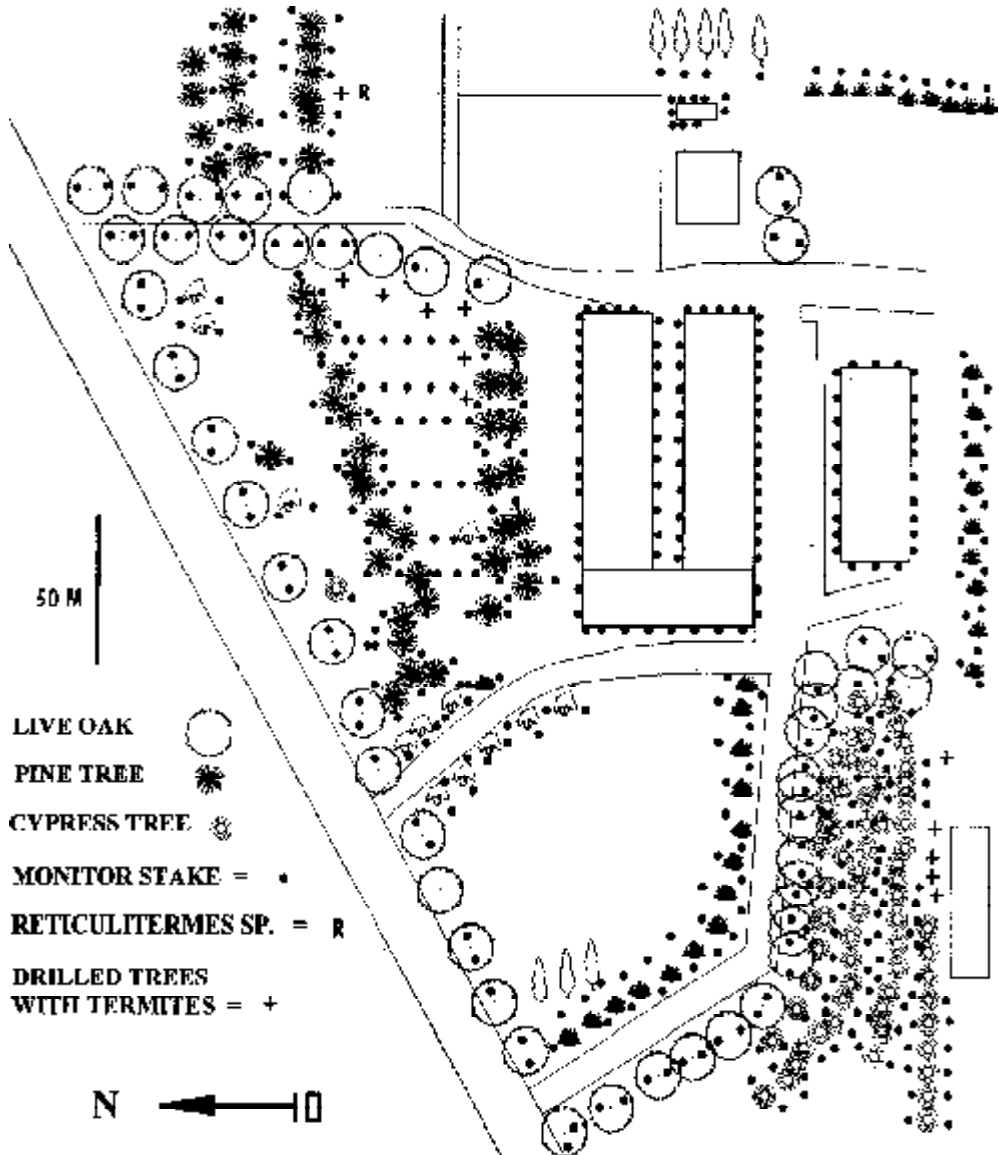


Figure 1. Diagrammatic representation of the Southern Regional Research Center, New Orleans, Louisiana, U.S.A., showing location of drilled trees infested with termites.



Figure 2. An example of structural failure of a tree with a termite-infested void.

cm) and then at a height of 30.5 cm on three other sides (labeled as north, west, south, and east). A Digital microProbe (DmP) was used for drilling (Sibert Technology Limited, Guildford, England). The DmP had a 500 mm by 1.5 mm diam. probe (bit) that would penetrate up to 350 mm into the trunk of a tree. Distance, probe rotations, and force are measured every 0.1 mm and transmitted in ASCII format to a computer via an RS-232 serial connector. Software supplied with the DmP creates graphs of the raw data, using Microsoft Excel, presenting graphs of the relative hardness of the wood drilled (Figure 3).  $R$  = radius from the center of the gallery to the surface of the tree and  $t$  = thickness of the healthy remaining wall were obtained from the graphs. When  $t/R < 0.35$ , a tree is considered a candidate for structural failure (Mattheck and Breloer, 1994). The percent of a tree that was hollowed was estimated by averaging the percent wood removed at each of the 4 samples taken at a height of 30.5 mm. Termites were identified to species using soldier keys (Scheffrahn and Su, 1994).

## RESULTS and DISCUSSION

The resistograph detected voids in wood and was sensitive enough to relative hardness that annual rings were also resolved (Figure 3A). The following termite-infested living trees were sampled (common names, genus and species, family, and number sampled): Bald cypress, *Taxodium distichum* Rich., Taxodiaceae, 5; live oak, *Quercus virginiana* Mill, Fagaceae, 4; loblolly pine, *Pinus taeda* L., Pinaceae, 3. *C. formosanus* infested all of the trees sampled except for one of the pines (PNEQ5; Table 3.), which was infested with *Reticulitermes* sp. Damage (voids) were detected in 3 of 5 bald cypress (60.0%). Two of the 3 bald cypresses with detected damage had  $t/R$  values  $< 0.35$ , indicating that they were candidates for failure (Table 1). Both of the bald cypress, which were candidates for failure, were estimated to have void damage exceeding 15% of a cross section of the structural wood. Two of the 4 infested oaks had internal damage. None of the infested oaks approached a  $t/R$  value of  $< 0.35$  (Table 2) and were therefore considered unlikely to fail. We had previously shown live oaks were infested 12.3 % of the time with *C. formosanus* (Osbrink et al., 1999). Two of the 3 infested pine trees, 66.6% had detectable amounts of wood removed. Both pines having detectable damage were considered candidates for failure using the

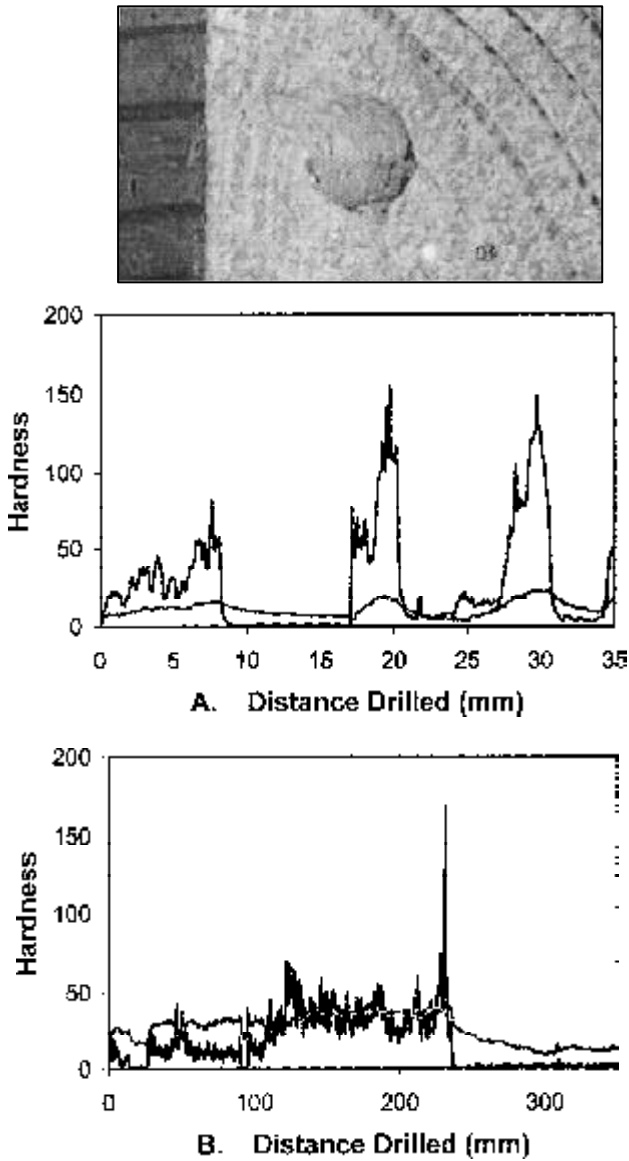


Figure 3. Resistograph charts, probe rotations (black line), and penetration force (gray line). A. Pine 2 X 4 drilled through rings with a 10 mm hole, photo (top) and graph. B. Oak tree drill graph indicating void beginning at ca. 240 mm into the trunk.

Table 1. Evaluation of internal damage in live trees attacked by *C. formosanus* at the Southern Regional Research Center, New Orleans, Louisiana, U.S.A.

ID	Tree Diam. (cm)	Sample Height (cm)	t/R <sup>1</sup>				% Void
			North	West	South	East	
CYPRESS							
CE1	62.3	30.5	0.31 <sup>2</sup>	0.48	0.16 <sup>2</sup>	0.14 <sup>2</sup>	19.9
		61.0	—	—	—	0.43	—
		91.4	—	—	—	0.24 <sup>2</sup>	—
		121.9	—	—	—	0.53	—
CW1	63.9	30.5	NA <sup>3</sup>	NA	NA	NA	0
		61.0	—	—	—	NA	—
		91.4	—	—	—	NA	—
		121.9	—	—	—	NA	—
CW2	46.9	30.5	0.26 <sup>2</sup>	0.26 <sup>2</sup>	0.26 <sup>2</sup>	0.34 <sup>2</sup>	40.7
		61.0	—	—	—	0.09 <sup>2</sup>	—
		91.4	—	—	—	NA	—
		121.9	—	—	—	NA	—
C2	44.5	30.5	NA	NA	NA	NA	0
		61.0	—	—	—	NA	—
		91.4	—	—	—	NA	—
		121.9	—	—	—	NA	—
C3	51.7	30.5	NA	NA	0.58	0.58	9.7
		61.0	—	—	—	0.76	—
		91.4	—	—	—	0.68	—
		121.9	—	—	—	0.59	—

<sup>1</sup> t = thickness of the healthy remaining wall, R = radius from the center of the void to the surface of the tree.

<sup>2</sup> t/R < 0.35 tree is in danger of failing.

<sup>3</sup> NA: there was no void detected to calculate t/R.

t/R criteria, even though % gallery damage was low (Table 3). Our previous study had shown pine had the highest incidence of termite infestation with 32.7 % infested with *C. formosanus* and 4.1% with *Reticulitermes* sp. (Osbrink et al., 1999). It should also be noted how critical it is to drill more than one side of the tree to detect galleries (Tables 2 and 3).

Though the occurrence of *C. formosanus* and *Reticulitermes* sp. in or on living trees has been observed before (Cooper and Grace, 1987; La Fage, 1985; Lai et al., 1983), there has been no documentation or quantification of potential hazard for tree failure nor the extent of gallery formation within an infested tree. In agreement with other researchers, we found the resistograph a viable tool for locating and quantifying internal structural loss of trees while causing minimal damage (Moore, 1999; Nicolotti and Miglietta, 1998; Mattheck et al., 1997; Mattheck et al., 1999). Information acquired with the resistograph can be incorporated into a decision-making process regarding the structural integrity (safety) and the suitability of a tree for drill and foam treatment or removal (Mattheck and Breloer, 1994; Rinn et al., 1996; Schwarze et al., 1997). Further, the precise locations of galleries within the trunk could be used to guide the placement of holes in a drill-and-foam tree treatment program. The absence of detected voids (41.7%) among infested trees included in this study indicate that the resistograph would not, by itself, be useful for determination of whether a tree is infested with termites. The resistograph should therefore be used to guide decisions concerning the soundness of the tree and to guide placement of treatments.

Table 2. Evaluation of internal damage in live trees attacked by *C. formosanus* at the Southern Regional Research Center, New Orleans, LA, U.S.A.

ID	Tree Diam. (cm)	Sample Height (cm)	t/R <sup>1</sup>				% Void
			North	West	South	East	
OAK							
SR1	91.4	30.5	NA <sup>3</sup>	NA	NA	NA	0
		61.0	—	—	—	NA	—
		91.4	—	—	—	NA	—
		121.9	—	—	—	NA	—
SR2	91.4	30.5	NA	NA	NA	NA	0
		61.0	—	—	—	NA	—
		91.4	—	—	—	NA	—
		121.9	—	—	—	NA	—
FEXE1	80.0	30.5	0.73 <sup>2</sup>	0.5	0.74	NA	8.9
		61.0	—	0.59	—	NA	—
		91.4	—	0.63	—	NA	—
		121.9	—	NA	—	NA	—
FEXW2	84.1	30.5	NA	0.73	NA	NA	1.5
		61.0	—	—	—	NA	—
		91.4	—	—	—	NA	—
		121.9	—	—	—	NA	—

<sup>1</sup> t = thickness of the healthy remaining wall, R = radius from the center of the void to the surface of the tree.

<sup>2</sup> t/R < 0.35 tree is in danger of failing.

<sup>3</sup> NA: there was no void detected to calculate t/R.

Table 3. Evaluation of internal damage in live trees attacked by *C. formosanus* at the Southern Regional Research Center, New Orleans, LA, U.S.A.

ID	Tree Diam. (cm)	Sample Height (cm)	t/R <sup>1</sup>				% Void
			North	West	South	East	
PINE							
PSR1	56.6	30.5	NA <sup>3</sup>	NA	NA	NA	0
		61.0	—	—	—	NA	—
		91.4	—	—	—	NA	—
		121.9	—	—	—	NA	—
PSR2	57.4	30.5	0.04 <sup>2</sup>	NA	NA	0.07	1.9
		61.0	—	—	—	NA	—
		91.4	—	—	—	NA	—
		121.9	—	—	—	NA	—
PNEQ5 <sup>4</sup>	51.7	30.5	0.84	0.72	NA	NA	2.7
		61.0	0.62	—	—	—	—
		91.4	0.06 <sup>2</sup>	—	—	—	—
		121.9	0.55	—	—	—	—

<sup>1</sup> t = thickness of the healthy remaining wall, R = radius from the center of the void to the surface of the tree.

<sup>2</sup> t/R < 0.35 tree is in danger of failing.

<sup>3</sup> NA: there was no void detected to calculate t/R.

<sup>4</sup> *Reticulitermes* sp.

## ACKNOWLEDGMENTS

We thank M. Cornelius, M. Wright, and D. Daigle for their invaluable assistance in reviewing drafts of the manuscript. We also thank A. Ballew for her technical assistance.

## REFERENCES

- Bethge, K., Mattheck, C., and Hunger, E. 1996. Equipment for detection and evaluation of incipient decay in trees. *Arboricultural J.* 20: 13-37.
- Cooper, P.A., and Grace, J.K. 1987. Associations of the eastern subterranean termite, *Reticulitermes flavipes* (Kollar) (Isoptera: Rhinotermitidae), with living trees in Canada. *J. Entomol. Sci.* 22: 353-354.
- Costello, L.R., and Quarles, S.L. 1999. Detection of wood decay in blue gum and elm: An evaluation of the resistograph and the portable drill. *J. Arboculture* 25: 311-318.
- Dolwin, J.A., Lonsdale, D., and Barnett, J. 1999. Detection of decay in trees. *Arboricultural J.* 23: 139-149.
- La Fage, J.P. 1985. Practical considerations of the Formosan subterranean termite in Louisiana: a 30-year-old problem. In: Tamashiro, M., and Su, N.-Y., eds. *Biology and control of the Formosan subterranean termite. Proceedings of the International Symposium on the Formosan Subterranean Termite. Research Extension Series 083, Hawaii Institute of Tropical Agriculture and Human Resources*, pp. 37-42.
- Lai, P., Y., Tamashiro, Y.M., Yates, J.R., Su, N.-Y., Fujii, J.K., and Ebesu, R.H. 1983. Living plants in Hawaii attacked by *Coptotermes formosanus*. *Proceedings, Hawaiian Entomol. Soc.* 24: 283-286.
- Mankin, R., Brandjost-Hubbard, J., Flanders, K., Zhang, M., Crocker, R., Lapointe, S., McCoy, C., Fisher, J., and Weaver, D. 2000. Eavesdropping on insects hidden in soil and interior structures of plants. *J. Econ. Entomol.* 93: 1173-1182.
- Mattheck, C., and Breloer, H. 1994. *The body language of trees: A handbook for failure analysis.* London: HMSO Publications. 240 pp.
- Mattheck, C., Bethge, K., and Albrecht, W. 1997. How to read the results of resistograph. *Arboricultural J.* 21: 331-346.
- Mattheck, C.G., Bethge, K.A., Burder, G.R., and Kappel, R. 1999. The resistograph: information for practical use. *Arborist News* 8: 42-44.
- Moore, W. 1999. The combined use of the resistograph and the shigometer for the accurate mapping and diagnosis of the internal condition of woody support organs of trees. *Arboricultural J.* 23: 273-287.
- Nicolotti, G., and Miglietta, P. 1998. Using high-technology instruments to assess defects in trees. *J. Arboculture* 24: 297-302.
- Osbrink, W.L.A., Woodson, W.D., and Lax, A.R. 1999. Populations of Formosan subterranean termite, *Coptotermes formosanus* (Isoptera: Rhinotermitidae), established in living urban trees in New Orleans, Louisiana, U.S.A. In: Robinson, W.H., Rettich, F., and Rambo, G.W., eds. *Proceedings of the 3rd International Conference on Urban Pests, Czech Republic: Graficke zavody Hronov*, pp. 341-345.
- Rinn, F., Schweingruber, F.-H., and Schar, E. 1996. Resistograph and X-ray density charts of wood comparative evaluations of drill resistance profiles and X-ray density charts of different wood species. *Holzforschung* 50: 303-311.
- Scheffrahn, R. H., and Su, N.-Y. 1994. Keys to soldiers and winged adult termites (Isoptera) of Florida. *Fla. Entomol.* 77: 460-474.
- Schwarze, F., Lonsdale, D., and Fink, S. 1997. An overview of wood degradation patterns and their implications for tree hazard assessment. *Arboricultural J.* 21: 1-32.

