NRL Report 6601

Termite Resistance of Polyvinyl Chloride Plastic—Two Years' Exposure in the Tropics

J. D. BULTMAN AND J. M. LEONARD

Marine Biology and Biochemistry Branch
Ocean Sciences Division

and

C. R. SOUTHWELL

Organic and Biological Chemistry Branch
Chemistry Division

October 20, 1967

NAVAL RESEARCH LABORATORY
Washington, D.C.

This document has been approved for public release and sale; its distribution is unlimited.

CONTENTS

Abstract	ii
Problem Status	ii
Authorization	ii
INTRODUCTION	1
EXPERIMENTAL PROCEDURE	1
Formulation Variables	1
Compounding Procedure	3
Exposure Technique	3
Rating System	5
RESULTS AND DISCUSSION	6
General	6
Comparison of Exposure Methods	6
Formulation Variables	7
Shrinkage and Embrittlement	12
SUMMARY	12
REFERENCES	13

ABSTRACT

An investigation of termite attack upon polymeric materials is in progress. So far, thirty-two formulations containing polyvinyl chloride resin have been prepared incorporating, variously, four plasticizers, three toxicants and two degrees of hardness. Of the 480 specimens exposed for about two years in the Panama jungle, 122 specimens (25%) show evidence of attack, ranging from light to heavy, although in general the attack was light. Seventy-seven of the damaged specimens contained no toxicant. Of the toxicants, lindane was generally more effective than either aldrin or dieldrin. Specimens containing dioctyl phthalate plasticizer had the highest incidence of attack, although, in the absence of a toxicant, specimens containing other plasticizers were attacked nearly as much. No significant difference in the incidence of attack developed between those specimens containing low and high percentages of silica. After two years' exposure, specimen shrinkage occurred in all samples plasticized with dioctyl adipate. This shrinkage was accompanied by an embrittlement which presumably added to termite resistance.

PROBLEM STATUS

This is an interim report; work on this project is continuing.

AUTHORIZATION

NRL Problem C03-02
Project Y-F015-06-03-201

Manuscript submitted June 9, 1967.

TERMITE RESISTANCE OF POLYVINYL CHLORIDE PLASTIC— TWO YEARS' EXPOSURE IN THE TROPICS

INTRODUCTION

From an economic standpoint, damage to materials and equipment caused by the activity of termites has long been a serious problem. Much of this damage has military significance, such as that resulting from destruction of polymeric insulating materials used on communications lines and in electronic equipment. Under the sponsorship of Naval Facilities Engineering Command, the Naval Research Laboratory is currently engaged in a program to investigate termite attack upon polymeric materials and to evaluate the resistance of various formulations. In the first phase of this work, plastics formulated from polyvinyl chloride resin are under study. It is hoped that a better understanding of the relationship between termites and this material will provide a basis by which polymers highly resistant to termite damage can be fabricated.

Prior investigations have been made elsewhere to determine the susceptibility of various proprietary plastics to damage by termites. Results of such programs, however, have been impaired because of the lack of information concerning the composition of these materials. To correct this deficiency, a series of polyvinyl chloride formulations was prepared at this Laboratory, so that the chemical composition of each is precisely known. Thus, it is hoped that a correlation between termite attack and chemical composition can be obtained.

The data presented in this report cover the cumulative results of termite attack on specimens of 32 polyvinyl chloride formulations which were placed on exposure in the Panamanian jungle in December 1964 and May 1965. Experimental details have been described in a preliminary report (1).

EXPERIMENTAL PROCEDURE

Formulation Variables

Plasticizers — The 32 polyvinyl chloride (PVC) formulations which were employed in this exposure incorporate, variously, four plasticizers, three toxicants and two degrees of hardness, as shown in Table 1. Commercially available grades of dioctyl phthalate (DOP), dioctyl adipate (DOA) and tricresyl phosphate (TCP) were used as plasticizers. TCP was chosen as a plasticizer because experimental results (2) indicate that PVC plasticized with TCP resists termite attack better than PVC plasticized to a comparable hardness with DOP. The commercial preparation of TCP, predominantly the para isomer, contains some of the ortho isomer. Although not shown specifically for termites, the general toxicity of the ortho isomer toward animal organisms suggests that the reported resistance may be attributed to its presence. To explore this point, TCP fortified with 30 wt-% of the ortho isomer (o-TCP) was used as the fourth plasticizer.

Toxicants — One potentially useful method to protect termite-susceptible synthetic material is the addition to the formulation of a chemical agent which imparts a toxic or repellant quality to the finished product. Aldrin, dieldrin, and lindane have had prior trials as such agents in the formulation of termite-resistant PVC plastics. Results of the experiments, however, are inconclusive because of the uncertainty of the degree of

Table 1
Composition of Polyvinyl Chloride Formulations

Formulation Number	Composition (Per Hundred Parts of Resin)												
	Toxicants			Plasticizers				Silica[1] (to Adjust Hardness)	Geon 101[2]	Carbon Black[3]	Lead Maleate[4]	Dibutyltin Laurate[5]	Whiting[6]
	Aldrin	Dieldrin	Lindane	TCP (Tricresyl Phosphate)	o-TCP (TCP Fortified with Ortho Isomer 30 wt-%)	DOP (Dioctyl Phthalate)	DOA (Dioctyl Adipate)						
1	—	—	—	100.0	—	—	—	20.0	100.0	2.0	3.5	2.0	30.0
2	1.3	—	—	100.0	—	—	—	20.0	100.0	2.0	3.5	2.0	30.0
3	2.6	—	—	100.0	—	—	—	20.0	100.0	2.0	3.5	2.0	30.0
4	—	1.3	—	100.0	—	—	—	20.0	100.0	2.0	3.5	2.0	30.0
5	—	2.6	—	100.0	—	—	—	20.0	100.0	2.0	3.5	2.0	30.0
6	—	—	1.3	100.0	—	—	—	20.0	100.0	2.0	3.5	2.0	30.0
7	—	—	2.6	100.0	—	—	—	20.0	100.0	2.0	3.5	2.0	30.0
8	—	—	—	100.0	—	—	—	50.0	100.0	2.0	3.5	2.0	30.0
9	—	—	—	—	100.0	—	—	20.0	100.0	2.0	3.5	2.0	30.0
10	1.3	—	—	—	100.0	—	—	20.0	100.0	2.0	3.5	2.0	30.0
11	1.6	—	—	—	100.0	—	—	20.0	100.0	2.0	3.5	2.0	30.0
12	—	1.3	—	—	100.0	—	—	20.0	100.0	2.0	3.5	2.0	30.0
13	—	2.6	—	—	100.0	—	—	20.0	100.0	2.0	3.5	2.0	30.0
14	—	—	1.3	—	100.0	—	—	20.0	100.0	2.0	3.5	2.0	30.0
15	—	—	2.6	—	100.0	—	—	20.0	100.0	2.0	3.5	2.0	30.0
16	—	—	—	—	100.0	—	—	50.0	100.0	2.0	3.5	2.0	30.0
17	—	—	—	—	—	100.0	—	20.0	100.0	2.0	3.5	2.0	30.0
18	1.3	—	—	—	—	100.0	—	20.0	100.0	2.0	3.5	2.0	30.0
19	2.6	—	—	—	—	100.0	—	20.0	100.0	2.0	3.5	2.0	30.0
20	—	1.3	—	—	—	100.0	—	20.0	100.0	2.0	3.5	2.0	30.0
21	—	2.6	—	—	—	100.0	—	20.0	100.0	2.0	3.5	2.0	30.0
22	—	—	1.3	—	—	100.0	—	20.0	100.0	2.0	3.5	2.0	30.0
23	—	—	2.6	—	—	100.0	—	20.0	100.0	2.0	3.5	2.0	30.0
24	—	—	—	—	—	100.0	—	50.0	100.0	2.0	3.5	2.0	30.0
25	—	—	—	—	—	—	100.0	20.0	100.0	2.0	3.5	2.0	30.0
26	1.3	—	—	—	—	—	100.0	20.0	100.0	2.0	3.5	2.0	30.0
27	2.6	—	—	—	—	—	100.0	20.0	100.0	2.0	3.5	2.0	30.0
28	—	1.3	—	—	—	—	100.0	20.0	100.0	2.0	3.5	2.0	30.0
29	—	2.6	—	—	—	—	100.0	20.0	100.0	2.0	3.5	2.0	30.0
30	—	—	1.3	—	—	—	100.0	20.0	100.0	2.0	3.5	2.0	30.0
31	—	—	2.6	—	—	—	100.0	20.0	100.0	2.0	3.5	2.0	30.0
32	—	—	—	—	—	—	100.0	50.0	100.0	2.0	3.5	2.0	30.0

[1]Silica - HiSil 303.
[2]Geon 101 - B.F. Goodrich polyvinyl chloride resin.
[3]Carbon black - Pelletex.
[4]Lead maleate - Trimal } stabilizers
[5]Dibutyltin laurate - Thermolite 12. }
[6]Whiting - witcarb "R".

retention of insecticide during the compounding process. Because of the close control exercised in the compounding of the present formulations, a reexamination of the effectiveness of these additives was made. Separate weight-loss studies indicated that under our milling conditions less than 1% of the added material was volatilized.

Hardness — The chief disadvantages associated with the use of toxicants as protective additives are that they limit the end use of the material; possibly lose their effectiveness over a period of time; and, because of their toxicity, may create handling problems for personnel. These disadvantages provide the impetus to investigate the use of hardness-controlling inert fillers as protective agents.

Damage by termites has been shown to have an inverse relationship to hardness for several plastic materials, including PVC (2). This resistance appears to result from purely mechanical impairment of the mandibular activity of the termites. Variation in the hardness of PVC can be achieved by controlling the amount of plasticizer; however, by this method hardness is obtained at the expense of flexibility. Hardness may be adjusted without serious loss of flexibility by adding a finely divided, inert material like silica. The latter method was employed to vary the hardness of the plastic in this work. The basic formulation for each plasticizer was adjusted to a hardness of 63 ± 2 (Shore durometer, Type A-2, 30 sec) by the addition of 20 pph of silica, while one formulation for each plasticizer was adjusted to a hardness of 76 ± 2 by the addition of 50 pph of silica. The silica used was HiSil 303, which is an extremely fine product having a particle size of about 25 mμ (Pittsburgh Plate Glass).

Compounding Procedure

The various plastics were prepared by compounding the ingredients of the formulations on a roller mill operated at a temperature of 260° to 270°F. The initial mix for each formulation consisted of the resin, whiting, and plasticizer. After these constituents were blended, carbon black, lead maleate, dibutyltin laurate, and silica were added, in the order given. After thorough mixing of the charge, the rolls were adjusted to give a 50-mil clearance and the material sheeted off. When a toxicant was part of the formulation, it was added to the mix just prior to sheeting so that it would receive a minimum exposure to heat. The total milling time for each charge was about 20 minutes; the milling time with the toxic additives was 5 minutes. The material, as it came from the mill, was sufficiently smooth and uniform to be used directly for preparing the specimens; the sheets were cut into 3 by 5 in. panels for later specimen fabrication.

Exposure Technique

The exposure site is located on Galeta Island at the Atlantic end of the Canal Zone. This test area has been used for various NRL termite exposure studies for the past ten years. It has a fairly heavy jungle canopy and local environmental conditions conducive to termite activity. A recent analysis of the termite population in this area indicated that the current predominant genus is *Heterotermes*, though *Coptotermes*, as reported earlier (1), has been known to be prevalent. A total of 480 plastic specimens, fifteen replicates each of the 32 PVC formulations, have been placed on exposure in two adjacent exposure beds which are shown in Fig. 1. These beds are located on the crest of a small hill which provides good drainage.

Exposure Bed A contains 320 randomly distributed specimens (ten replicates per formulation) which were buried in December 1964. Each specimen was secured about a 1-in.-diameter, 5-in.-long oak dowel by monel staples and PVC cement. The open ends

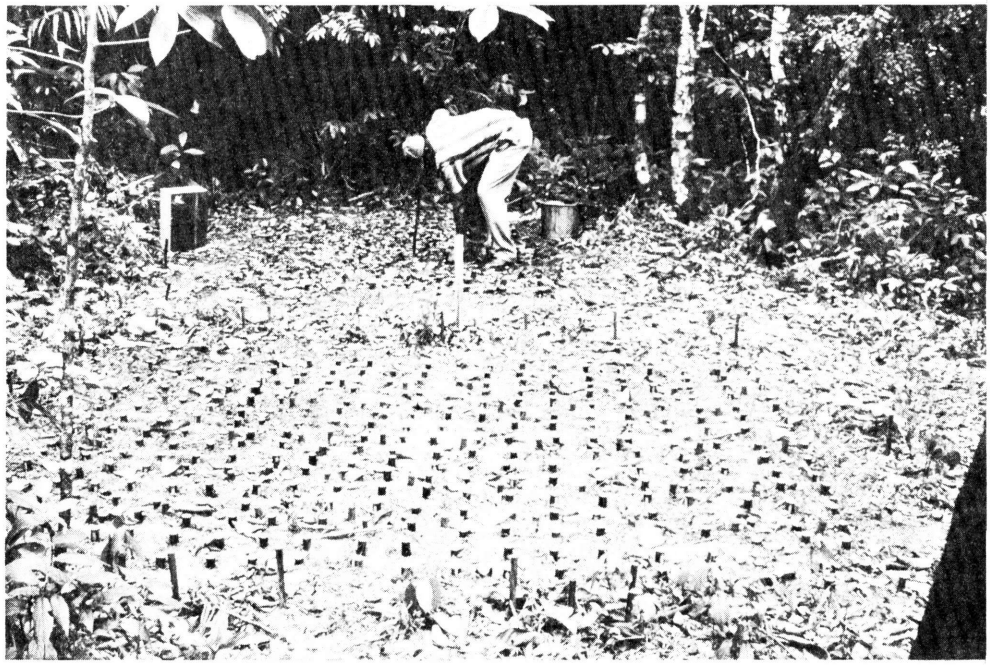


Fig. 1 - Polyvinyl chloride exposure beds: Bed A is in the foreground, Bed B in the background

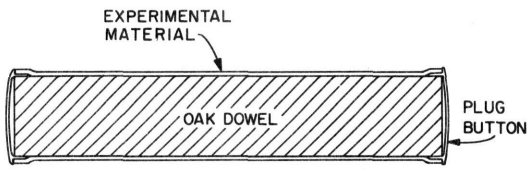


Fig. 2 - A typical exposure specimen

of the dowel were capped with metal plug buttons* as shown in Fig. 2. Oak was chosen as a support for the specimens because of its attractiveness to termites. Initially, the specimens were buried in a vertical position, 1 ft on center, with the top of each dowel about 1-in. below the ground line. During a subsequent inspection, however, the specimens were reburied so that about 1-in. of the dowel remained above the ground to facilitate the location of the specimens on future inspections. The exposure bed was seeded with 48 evenly distributed bare oak dowels, to serve as bait and as indices of the termite activity of the area.

Exposure Bed B contains 160 specimens (five replicates per formulation) which were placed on exposure five months later, in May 1965. The purpose of this second bed was to explore the use of other exposure methods. In order to compare the two beds, one of the methods employed in Bed B was identical to that used in Bed A. All samples in Bed B were also secured about 1 by 5 in. dowels. In this case both oak and cativo (Prioria copaifera), a native wood very susceptible to termite attack, were used. Each of the five replicates was exposed in a different manner, viz.; the ends of the dowels were capped with solid plug buttons, capped with screened plug buttons, or left exposed; the assembled specimens were partially buried in a vertical position or placed horizontally on the jungle floor, with or without an added cativo bait stake fastened to the exterior.

*Plug buttons are small, many-tined ferrous metal caps, solid or screened, which are used to cover openings in chassis of electronic equipment.

In addition to exposure Beds A and B, 15 specimens of each formulation were sent to the Wood Products Insect Laboratory, of the U.S. Department of Agriculture, at Gulfport, Mississippi. Temperature-climate termite resistance of the formulations is being evaluated at Gulfport by WPIL. Their exposure results through one year have been reported (3,4).

Rating System

The specimens are rated by visual inspection, according to the following numerical system:

0 - no visible termite damage to the plastic

1 - etching or very slight attack on the plastic

2 - termites cutting into the plastic

3 - termites cutting into the plastic to a depth approximating 1/2 its thickness (specimen thickness — 50 mils)

4 - termites cutting into the plastic to a depth exceeding 1/2 its thickness

5 - complete penetration of the plastic

A second rating system is used for evaluating termite attack on the bait dowels as follows: S - slight; M - moderate; H - heavy; VH - very heavy; X - missing. The bait dowels shown in Fig. 3 illustrate these ratings.

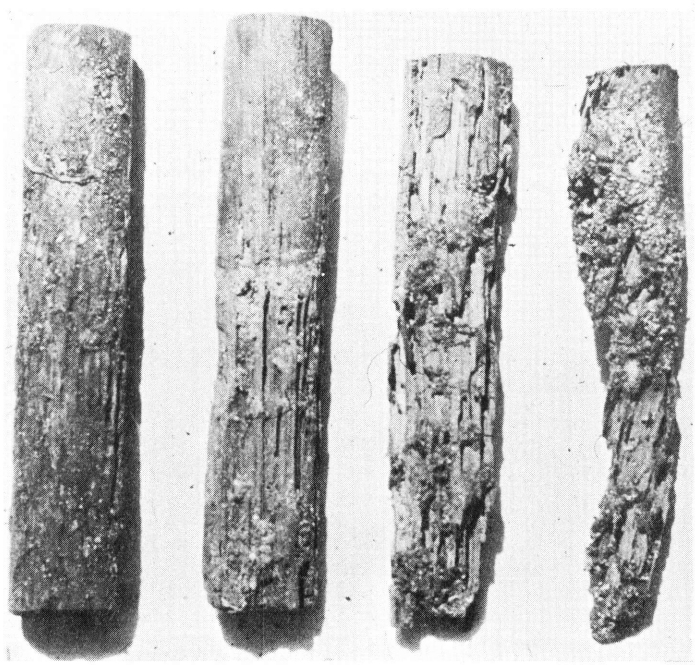


Fig. 3 - Bait dowels showing varying degrees of termite attack ranging (left to right) from slight (S) to very heavy (VH)

RESULTS AND DISCUSSION

General

The first full inspection of both exposure beds was made in mid-February 1966, and the inspection results were reported in Ref. 1. A second full inspection, representing 26 months' exposure for Bed A and 21 months for Bed B, was performed in mid-February 1967, and is the subject of this report.

At the beginning, forty-eight 1-in.-diameter, 5-in.-long bare oak dowels were distributed in Bed A. The dowel stakes were buried vertically to a depth of 2/3 their length. These samples serve the dual purpose of supplying termite bait in the test area and providing a check on bed activity during the exposure interim. After the February 1966 inspection, 14 new dowels were added to Bed A. In Bed B, 96 of the plastic specimens were exposed with adjacent 1/2 by 1/2 by 4 in. half-buried stakes of cativo (Prioria copaifera). These served a similar purpose as combination bait and check samples. After the February 1966 inspection, 15 oak dowels were added to this bed to evaluate the next year's activity.

During the first exposure period of 14 months, all 48 of the bait dowels in Bed A sustained some termite damage, 16 receiving heavy to very heavy attack. During this second year, attack on these dowels generally increased an average of one step on the rating scale; the modal rating increased from "moderate" to "very heavy." The 14 new stakes added to Bed A in February 1966 were inspected, and after 12 months' exposure, only eight had termite damage and just one rated heavy attack. The 1967 inspection of Bed B, representing 21 months' exposure, was the first complete inspection of the bait wood. Of the 96 cativo stakes initially affixed to specimens, 25 were missing; thus, the degree of termite attack on these is unknown, although most were probably termite-destroyed. Of the remaining 71 samples, 23 had definite signs of termite damage. The 48 not attacked by termites were usually heavily infected by fungi. Of the 15 oak dowels installed in 1966 to check interim activity, ten sustained perceptible damage, but none had more than moderate attack.

Results of these bait-check inspections indicate that there was a fairly good distribution of termites throughout both beds; although the incidence of active termites seemed rather low, only four specimens in each bed were found to contain live *Heterotermes*. As measured by the interim check stakes, the intensity of attack in Bed A seems to have fallen off somewhat during the second year.

In the hopes of inducing increased termite activity in the test area in 1967, a large number of bait-check stakes was installed at the completion of the February inspections. One hundred and fifteen 3/4 by 3/4 by 12 in. southern pine stakes were driven vertically to one-half depth. In addition, the perimeter of each bed was baited with 4 by 6 by 3/4 in. pine panels placed end to end and lying flat.

Comparison of Exposure Methods

For the plastic specimens in Bed A, the general distribution of attack is presented in Table 2. This table shows the location in the bed of each damaged specimen, the amount of damage, and its formulation. A similar display for Bed B is presented in Table 3. Those positions which have no entry are, as yet, undamaged samples. From these tables it can be seen that termite activity among the plastic specimens has been reasonably uniform in the beds, both in terms of distribution and degree of attack, except perhaps for a slightly higher attack among those specimens in the lower right quadrant of Bed B.

Table 2
Termite Activity as a Function of Specimen Location and Formulation
(Bed A - Exposure Period 26 Months)

Row	Column 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1				16-2	18-3	26-2		16-4								
2	5-2*				17-3	9-1		1-2				8-2	16-1		24-2	
3				28-2		20-2		22-1	24-3	17-3				17-2		
4				16-3	25-3	10-1		13-1			32-2					
5				18-3	18-3								24-3		20-1	
6						9-1									24-5	17-2
7	17-1		1-3													20-2
8				19-1										8-1	20-2	
9		26-2	1-3					25-1							9-2	
10						19-2		20-2			21-1		5-1		17-3	
11							1-3				12-1					17-3
12																
13		25-2		8-1					9-2		32-4					
14	9-1									24-2					5-1	
15			8-2				9-5									20-2
16	17-2						13-1			24-5					25-1	
17	17-2			30-2					24-5	18-1						
18	25-2									25-2	8-2	24-2				
19									1-1	21-3					8-5	17-5
20			21-1	25-3		25-5				1-3		1-5		8-2		

*Example: Formulation 5, attack rating 2.

After the first 9 months' exposure, damage in Bed B was so slight as to warrant no further comment; however, during the ensuing year some activity had occurred. The data are summarized in Table 4. Although there is a slight difference in the number of specimens attacked in each category, no exposure method differs conspicuously from the others. Therefore, it was concluded that all the exposure methods employed were essentially equivalent at this stage and that data obtained from the specimens in both beds could be combined.

Formulation Variables

Of the 480 specimens exposed, 122 have sustained some degree of attack, ranging from very slight to complete penetration of the plastic. Of this number, 79 were located in Bed A, in which only 21 instances of attack were previously recorded (1). From

Table 3
Termite Activity as a Function of Specimen Location and Formulation
(Bed B - Exposure Period 21 Months

		Column										
		1	2	3	4	5	6	7	8	9	10	11
Row	1	1-3*					16-1			25-1		
	2	1-3								25-1		
	3	1-5					16-3					
	4							19-2		25-2		
	5	1-2								25-5		
	6			8-2								
	7	2-2	5-1				17-4	20-2		26-1		
	8		5-1				17-3	20-1				32-1
	9						17-2					
	10		5-4	8-3			17-3	20-1				
	11			9-3				21-1		27-1		†
	12		6-1	9-1			18-2	21-2	24-3			†
	13			9-1			18-1		24-5			†
	14			9-3			18-1		24-4			†
	15							21-2	24-4	27-2		†

*Example: Formulation 1, attack rating 3.
†No specimen.

Table 4
Evaluation of Exposure Methods Used in Bed B

Replicate	Exposure Method	Attack Ratings	Cumulative Rating
1	Oak center, open ends, no external stake, horizontal orientation	1 1 1 1 2 3 3	12
2	Cativo center, solid ends, cativo stake, vertical orientation	1 1 1 2 2 2 2 3 3 4	21
3	Cativo center, screen-cap ends, cativo stake, vertical orientation	1 1 1 1 1 3 3 5 5	21
4	Oak center, solid-cap ends, cativo stake, vertical orientation	1 2 2 2 3 4	14
5	*Oak center, solid-cap ends, no external stake, vertical orientation	2 2 2 3 4 4 5	22

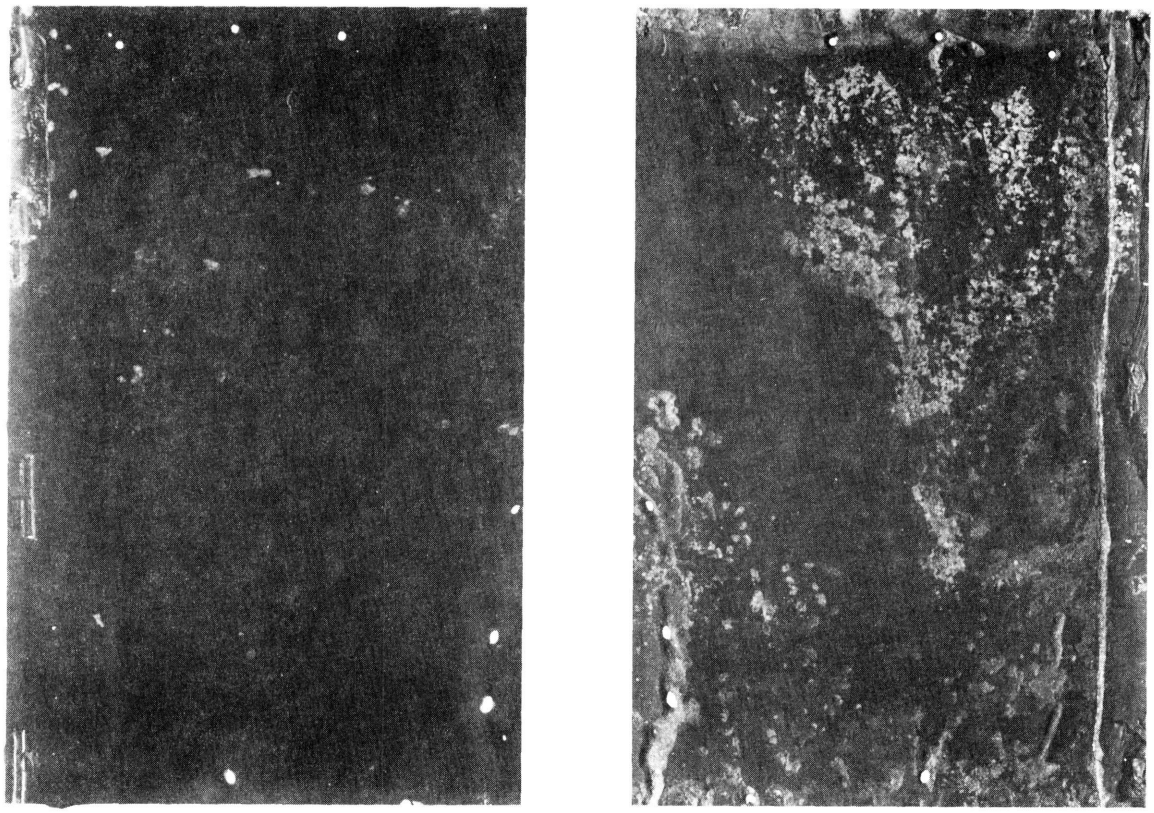
*This method of exposure was used for all specimens in Bed A.

inspection of Table 5, it can be seen that the general level of attack was not high. In no instance was every specimen of a given formulation damaged, and in only five formulations were ten or more attacked. Conversely, all the specimens of nine formulations remained in an undamaged state. A special consideration should also be given to those specimens with an attack rating of 1; such rating may only reflect an exploratory nibbling by the organisms which discouraged them from further activity, rather than indicate a real susceptibility of the plastic.

Table 5
Attack Rating for Both Beds as a Function of Formulation

No.	Formulation	Panel Ratings	No. Specimens Attacked[1]	Cumulative Rating
1	TCP, LoSil[2]	1 2 2 3 3 3 3 3 3 5 5	11	33
2	TCP, 1.3% A[4]	2	1	2
3	TCP, 2.6% A		0	0
4	TCP, 1.3% D[5]		0	0
5	TCP, 2.6% D	1 1 1 1 2 4	6	10
6	TCP, 1.3% L[6]	1	1	1
7	TCP, 2.6% L		0	0
8	TCP, HiSil[3]	1 1 2 2 2 2 2 3 5	9	20
9	o-TCP, LoSil	1 1 1 1 1 2 2 3 3 5	10	20
10	o-TCP, 1.3% A	1	1	1
11	o-TCP, 2.6% A		0	0
12	o-TCP, 1.3% D	1	1	1
13	o-TCP, 2.6% D	1 1	2	2
14	o-TCP, 1.3% L		0	0
15	o-TCP, 2.6% L		0	0
16	o-TCP, HiSil	1 1 2 3 3 3 4	7	17
17	DOP, LoSil	1 2 2 2 2 2 3 3 3 3 3 3 4 5	14	38
18	DOP, 1.3% A	1 1 1 2 3 3 3	7	14
19	DOP, 2.6% A	1 2 2	3	5
20	DOP, 1.3% D	1 1 1 2 2 2 2 2 2	9	15
21	DOP, 2.6% D	1 1 1 2 2 3	6	10
22	DOP, 1.3% L	1	1	1
23	DOP, 2.6% L		0	0
24	DOP, HiSil	2 2 2 3 3 3 4 4 5 5 5 5	12	43
25	DOA, LoSil	1 1 1 1 2 2 2 2 3 5 5	11	25
26	DOA, 1.3% A	1 2 2	3	5
27	DOA, 2.6% A	1 2	2	3
28	DOA, 1.3% D	2	1	2
29	DOA, 2.6% D		0	0
30	DOA, 1.3% L	2	1	2
31	DOA, 2.6% L		0	0
32	DOA, HiSil	1 2 4	3	7

[1]Specimens attacked out of a total of 15 replicates per formulation.
[2]LoSil--20 pph silica in formulation (basic formulation).
[3]HiSil--50 pph silica in formulation.
[4]A--Aldrin.
[5]D--Dieldrin.
[6]L--Lindane.



(a) Front (b) Back

Fig. 4 - Heavily damaged PVC panel showing eight penetrations and deep channeling

A photograph of a heavily damaged specimen is presented in Fig. 4. This specimen, which contains DOP and the higher concentration of silica, has been penetrated in several places for a rating of 5. Close scrutiny indicates that these penetrations have been made from within the specimen. There is a rather deep channel cut in the plastic on the underside, one end of which terminates at a plug button. This channel was probably the main point of entry for the termites. In addition, two other, lesser channels were observed which also lead to the edges of the specimen, between the tines of the plug buttons. When the specimen was removed it contained live termites, and the supporting dowel was almost completely disintegrated.

Plasticizers — Effect of plasticizers can be evaluated from the summarized comparisons presented in Table 6 and from the complete results shown in Table 5. These data disclose that the plasticizers have not contributed appreciably to the resistance of the plastic. The different attack frequencies when subjected to a chi-square test show significance only above the 10% level. Data at such a level suggest, but do not necessarily indicate, differences.

When both frequency and intensity of attack are considered, however, a mild advantage for the o-TCP is more strongly suggested. Cumulative ratings were 20 for o-TCP, 25 for DOA, 33 for TCP, and 38 for DOP. The comparatively low resistance of plain TCP is somewhat surprising in view of the results of Gay and Wetherly (2), which indicated that TCP acted in its own right as a protective agent.

Table 6
Summary of Termite Activity

Pertinent Component	Specimens Damaged		Average Rating of Damaged Specimens	Specimens Penetrated	Remarks
	Number	Percent			
Comparison of Silica Contents					
Low Silica	35/45*	78	2.6	4	Each with 3 plasticizers (DOA excluded because of hardening; see text)
High Silica	28/45	62	2.9	5	
Comparison of Plasticizers					
TCP	11/15	73	3.0	2	Each with low silica and no toxicant
o-TCP	10/15	66	2.0	1	
DOP	14/15	93	2.8	1	
DOA	11/15	73	2.3	2	
Comparison of Toxicants					
Aldrin	17/120	14	1.8	0	Each with two concentrations of toxicants and four plasticizers
Dieldrin	25/120	21	1.6	0	
Lindane	3/120	2	1.3	0	
None	77/120	64	2.6	11	Includes high and low silica with four plasticizers

*Example: 35 samples attacked out of 45 exposed.

Those specimens plasticized with DOP seem to have the lowest resistance, and by reference to Table 5, it can be seen that when all formulations are considered (high and low silica, with and without toxicants) an even larger proportion of the damaged samples contained DOP. But, one must remember that present differences from plasticizers are too small to be more than indicative of probable differences in termite resistance.

Toxicant — Referring again to Tables 5 and 6, it is obvious that the bio-inhibitors have provided the largest measure of protection for the plastics. This is not surprising because of their general toxic properties. Because of the similarity in level of attack, the data for both concentrations of each toxicant have been combined in Table 6. There are anomalies in which a better degree of protection was afforded a specimen containing a lesser amount of the same toxicant. Results such as these are not unusual, however, when working with biological systems.

There are two interesting points in the data with regard to toxic additives. First, lindane has been a very effective agent. Only three specimens out of 120 exposed have been attacked; and these were only light attacks and only on the samples at the lower lindane concentrations. Second, the dieldrin and aldrin were also effective, except in the presence of DOP. The effectiveness of lindane may be due to its vapor pressure, which is higher than that of the other two toxicants by several orders of magnitude. There could be a sufficient concentration of this material in the vapor phase along the outer surface of the plastic to act as a repellant, thereby discouraging the organisms from making even exploratory nibbles. If this is true, it should be borne out by subsequent data. One would expect the attack rate of these specimens to rise rapidly as the residual supply of lindane is exhausted.

Hardness — To evaluate the effect of hardness, we exclude the DOA group, for reasons to be given later. Comparing the low- and high-silica formulations for the rest indicates there is little difference (cumulative attack ratings of 92 versus 80) for the two respective hardnesses afforded by the two levels of silica.

It should be pointed out, however, that this has been a very limited exploration of hardness additives. One material, silica, was tested only as an ultra-fine powder, and at just two concentrations. The considerable advantages to be gained with inert filler methods of control seem to warrant additional investigation of such methods.

Shrinkage and Embrittlement

In the earlier report (1) it was noted that some of the plastics were shrinking away from the ends of their supporting dowels and that the shrinkage was related in some way to the nature of the plasticizer. At that time, 40% of those specimens containing DOA as the plasticizer showed this phenomenon, whereas only 3% of those specimens containing other plasticizers did so. The latest inspection shows that shrinkage has continued and has become more widespread. It was observed to occur almost exclusively among those specimens containing DOA as the plasticizer: 56 out of 80 DOA specimens (70%) were markedly affected; all 80 of them showed some evidence of shrinkage.

This shrinkage was most probably caused by a loss of the plasticizer; and it was accompanied by an embrittlement of the material. Since it has been shown (2) that rigid PVC plastic, i.e., plastic containing little or no plasticizer, is very resistant to damage by termites, this embrittlement should cause a significant decrease in future attack. Indeed, this may already be the case for those specimens of Formula 32 (Table 5) which were somewhat harder from the start, as a consequence of added silica.

SUMMARY

Although not extremely heavy, there has been a considerable increase in the incidence of attack on the plastics since the last inspection. This increase has been sufficient to show that termite activity is reasonably uniform in both beds, and to establish some trends. The emerging pattern indicates that dioctyl phthalate may not be a desirable plasticizer to use in formulating polyvinyl chloride plastics for use where termite damage is possible. Similarly, neither of the tricresyl phosphate plasticizers has provided the outstanding service that was expected. Within the limited range of hardness studied here, varying internal hardness of the plastic by adding inert fillers has shown no significant effect; however, advantages to be gained by this method make it well worth additional study.

Those plastics containing toxicants have undergone the least amount of Attack. Aldrin and dieldrin have been almost equally effective in providing protection, but neither agent has been as generally effective as lindane. Lindane, because of its much higher vapor pressure, may be acting as a repellant which would account for the low incidence of attack for lindane-containing specimens. The concentration of lindane will decrease with continuing vaporization; therefore, it should be watched carefully for its long-term effectiveness.

Finally, an interesting development has taken place with regard to those specimens plasticized with dioctyl adipate. These specimens are shrinking upon their supporting dowels, presumably because of a loss of plasticizer. This loss has been sufficient in most instances to cause embrittlement of the plastic. The higher resistance found for samples combining dioctyl adipate with high silica can probably be attributed to the dual hardening effect of these two constituents.

At this time no single plasticizer or combination of plasticizer and additive can be specified for obtaining complete termite resistance. However, if long-term retention of insecticide efficiency can be demonstrated, lindane combined with one of the nonshrinking formulations may eventually prove adequate for the requirements.

It is hoped that sufficient attack will take place in the coming year so that more definitive comparisons can be made between the various formulations. At the same time a second exposure program investigating other resins and a wider range of additives will be initiated.

REFERENCES

1. Bultman, J.D., Leonard, J.M., and Southwell, C.R., "Termite Resistance of Polyvinyl Chloride Plastics," NRL Memorandum Report 1704, June 1966

2. Gay, F.J., and Wetherly, A.H., "Laboratory Studies of Termite Resistance IV. The Termite Resistance of Plastics," Commonwealth Scientific and Industrial Research Organization, Division of Entomology Technical Paper 5, 1962

3. Beal, R.H., and Tynes, K.E., "Testing of Wire Insulating Materials for Resistance to Termites," Establishment Report, U.S.D.A. Wood Products Insect Laboratory, Gulfport, Mississippi, June 1966

4. Beal, R.H., and Tynes, K.E., "Testing of Wire Insulating Materials for Resistance to Termites," First Annual Field Progress Report, U.S.D.A. Wood Products Insect Laboratory, Gulfport, Mississippi, Jan. 1967

This page intentionally left blank.

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*

Naval Research Laboratory
Washington, D.C. 20390

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE

TERMITE RESISTANCE OF POLYVINYL CHLORIDE PLASTIC—
TWO YEAR'S EXPOSURE IN THE TROPICS

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
An interim report on a continuing problem.

5. AUTHOR(S) *(First name, middle initial, last name)*

J.D. Bultman, J.M. Leonard, and C.R. Southwell

6. REPORT DATE
October 20, 1967

7a. TOTAL NO. OF PAGES
18

7b. NO. OF REFS
4

8a. CONTRACT OR GRANT NO.
NRL Problem C03-02

b. PROJECT NO.
Y-F015-06-03-201

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

NRL Report 6601

9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Department of the Navy
(Naval Facilities Engineering Command)
Washington, D.C. 20360

13. ABSTRACT

An investigation of termite attack upon polymeric materials is in progress. So far, thirty-two formulations containing polyvinyl chloride resin have been prepared incorporating, variously, four plasticizers, three toxicants and two degrees of hardness. Of the 480 specimens exposed for about two years in the Panama jungle, 122 specimens (25%) show evidence of attack, ranging from light to heavy, although in general the attack was light. Seventy-seven of the damaged specimens contained no toxicant. Of the toxicants, lindane was generally more effective than either aldrin or dieldrin. Specimens containing dioctyl phthalate plasticizer had the highest incidence of attack, although, in the absence of a toxicant, specimens containing other plasticizers were attacked nearly as much. No significant difference in the incidence of attack developed between those specimens containing low and high percentages of silica. After two years' exposure, specimen shrinkage occurred in all samples plasticized with dioctyl adipate. This shrinkage was accompanied by an embrittlement which presumably added to termite resistance.

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0101-807-6801

Security Classification

Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Tropical termites						
Electrical insulation						
Toxicant						
Aldrin						
Dieldrin						
Lindane						
Termite resistant plastics						
Plasticizers						
o-TCP — tricresyl phosphate fortified with the ortho isomer						
DOP — dioctyl phthalate						
DOA — dioctyl adipate						
TCP — tricresyl phosphate						
Plastic hardness						

DD FORM 1 NOV 65 1473 (BACK) GPO 931-720

(PAGE 2)

Security Classification