TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
TX-89/1135-2F		

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code
Prevention of Fire Ant Damage to Signal Control	July 1989
7. Author(s): William P. MacKay, Saïd O. Majdi, S. Bradleigh Vinson, and Carroll J. Messer	8. Performing Organization Report No.: Research Report 1135-2F
9. Performing Organization Name and Address: Texas Transportation Institute, The Texas A&M University System, College Station, Texas 77843-3135	10. Work Unit No. / 11. Contract or Grant No.: Study No. 2-18-86-1135
12. Sponsoring Agency Name and Address: State Department of Highways and Public Transportation, Safety and Maintenance Operations Division, P.O. Box 5051, Austin, Texas 78763-5051	13. Type of Report and Period Covered: Final, September 1985 – July 1989 / 14. Sponsoring Agency Code

15. Supplementary Notes

Research Study Title: Prevention of Fire Ant Damage to Signal Control
Research Sponsored by: Texas State Department of Highways and Public Transportation

16. Abstract

This report is the last and final report which addresses the problem of imported fire ants infesting traffic signal control cabinets. The study focused on developing and testing treatments for minimizing fire ant infestation of traffic signal cabinets. A treatment program based on annual maintenance inspections and use of the granular insecticide chlorpyrifos is recommended. An extensive series of laboratory and field studies were conducted to determine the attraction phenomena of fire ants to signal cabinets. Electric fields and protected environment appear to be the principal attractors of fire ants to signal cabinets.

This research was sponsored with state funds by the Texas State Department of Highways and Public Transportation in Austin, Texas.

17. Key Words	18. Distribution Statement
Traffic Signals Fire Ants Signal Maintenance	No Restrictions. This document is available to the public through the National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	61	

Form DOT F 1700.7 (8-69)

PREVENTION OF FIRE ANT DAMAGE TO SIGNAL CONTROL

by

William P. MacKay
Research Scientist

Saïd O. Majdi
Engineering Research Associate

S. Bradleigh Vinson
Professor of Entomology

and

Carroll J. Messer
Research Engineer

Research Report 1135-2F
Research Study 2-18-86-1135
"Prevention of Fire Ant Damage to Signal Control"

Sponsored by

Texas State Department of Highways and Public Transportation
(State Funded)

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

and

TEXAS AGRICULTURAL EXPERIMENT STATION
The Texas A&M University System
College Station, Texas 77843-2475

July 1989

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
in²	square inches	645.2	millimetres squared	mm²
ft²	square feet	0.0929	metres squared	m²
yd²	square yards	0.836	metres squared	m²
mi²	square miles	2.59	kilometres squared	km²
ac	acres	0.395	hectares	ha

MASS (weight)

Symbol	When You Know	Multiply By	To Find	Symbol
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

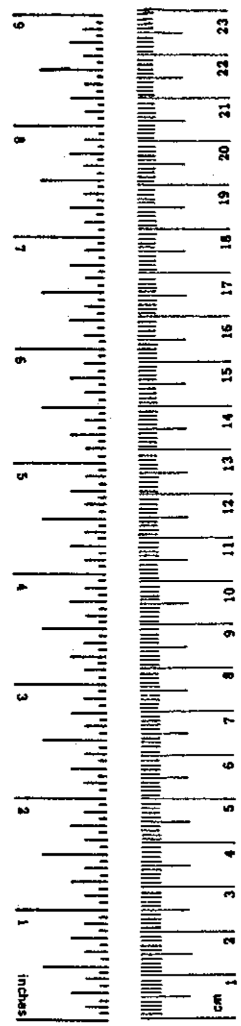
VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft³	cubic feet	0.0328	metres cubed	m³
yd³	cubic yards	0.0765	metres cubed	m³

NOTE: Volumes greater than 1000 L shall be shown in m³.

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
mm²	millimetres squared	0.0016	square inches	in²
m²	metres squared	10.764	square feet	ft²
km²	kilometres squared	0.39	square miles	mi²
ha	hectores (10 000 m²)	2.53	acres	ac

MASS (weight)

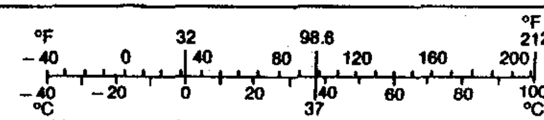
Symbol	When You Know	Multiply By	To Find	Symbol
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m³	metres cubed	35.315	cubic feet	ft³
m³	metres cubed	1.308	cubic yards	yd³

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

ABSTRACT

This report is the last and final report which addresses the problem of imported fire ants infesting traffic signal control cabinets. The study focused on developing and testing treatments for minimizing fire ant infestation of traffic signal cabinets. A treatment program based on annual maintenance inspections and use of the granular insecticide chlorpyrifos is recommended. An extensive series of laboratory and field studies were conducted to determine the attraction phenomena. Electric fields and protected environment appear to be the principal attractors of fire ants to signal cabinets.

KEY WORDS: Traffic Signals, Fire Ants, Signal Maintenance.

PROJECT SUMMARY

In this research project, it has been clearly established through an extensive series of laboratory and field studies that fire ants are:

1. Attracted to electric fields and electromechanical relays.
2. Not attracted to magnetic fields, ozone, or insulation on wires.

We have provided a short-term solution to fire ant infestation by using:

1. A chlorpyrifos-based insecticide for controlling ants in cabinets.
2. The sealing of electromechanical relay switches which prevents ants from damaging the switches.

A combination of these two methods should control ants in most or all of the traffic signal cabinets in Texas.

Detailed, step-by-step field inspection and treatment procedures were developed and provided in this report for use by traffic signal technicians to implement the research findings.

IMPLEMENTATION

The implementation of the results of this research project is described in chapter V in a series of recommendations and procedures for dealing with the imported red fire ant infestation problem in traffic signal cabinets. These recommendations and procedures could be converted to a technical manual to be distributed to signal maintenance technicians.

ACKNOWLEDGMENTS

We would like to thank Awinash Bhatkar for critically reading the manuscript, James Irving for providing technical assistance and production efforts of the experimentation apparatus, and Stan Swinton (D-18T) for discussions of the project. Alan Dean identified the spider. John Black and Gary Lange allowed us to use the College Station cabinets, and Lee Robinson, Jerry Hejl and Mark Schoenemann assisted us with the field work. J.W. Chism, George Mitchell and Kelly Milligan allowed us to use the cabinets in Bryan. The research was supported by the Texas State Department of Highways and Public Transportation, study number 2-18-26-1135. Stan Swinton (D-18T) served as the study's technical coordinator for SDHPT. Bill Cargile of Rainbow Manufacturing Corporation, P.O. Box 26445, Birmingham, AL 35226, supplied the chlorpyrifos product (Insect Control); Nancy Coplin of Stutton Corporation, 1400A Karen Ave., Austin, TX 78757, and C.M. Carleton of State Chemical Manufacturing Co., Cleveland, OH 44114, supplied the pyrethrin products JS 685 and 797A, respectively. Barbara Cheazes of Rainbow Manufacturing Corporation answered numerous technical questions about various insecticides used in this study.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration, the State Department of Highways and Public Transportation, the Texas Transportation Institute, or the Texas Agricultural Experiment Station. This report does not constitute a standard, specification or regulation.

Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the Texas Agricultural Experiment Station and does not imply its approval to the exclusion of other products that may also be available.

TABLE OF CONTENTS

I. INTRODUCTION 1

1. Research Problem 1
2. Research Program 3

II. SURVEY OF THE FIRE ANT PROBLEM IN SOUTHEASTERN UNITED STATES AND POTENTIAL SOLUTIONS 5

1. Traffic Signal Design and Construction 6
2. Signal Maintenance 8
3. Conclusions 8

III. LABORATORY EXPERIMENTS 9

1. Attraction of Fire Ants to Varying AC Frequencies 9
2. Attraction of Fire Ants to Relay Switches 11
3. Effect of Ozone on Fire Ants 13
4. Effect of Magnetic Fields on Ants 13
5. Attractiveness of Electric Fields to Fire Ants 15
6. Durability of Wire Insulation Exposed to Fire Ants 30
7. Electric Trap for Reducing Fire Ant Infestation Problem . . 30

IV. FIELD EXPERIMENTS 33

1. Effectiveness of Insecticides in Controlling Fire Ant Populations in Traffic Control Cabinets 33
2. Preventing Fire Ants from Entering Relay Switches 39

V. CONCLUSIONS AND RECOMMENDATIONS 44

1. General Conclusions 44
2. Laboratory Conclusions 46
3. Recommended Treatment Program 46

VI. FUTURE RESEARCH 50

REFERENCES 51

LIST OF FIGURES

1	Fire Ant Distribution in the United States	2
2	Attraction of Fire Ants to AC Frequencies During First Five Successful Experiments	10
3	Laboratory Data Comparing Numbers of Imported Fire Ants in Active and Inactive Relays	12
4	Apparatus Used in the Magnetic Field Experiments	14
5	Apparatus Used in DC Electric Field Experiments	16
6	Apparatus Used in AC Electric Field Experiments	17
7	Effect of Electric Field on Species Solenopsis Invicta	18
8	Effect of Electric Field on Species Solenopsis Geminata	19
9	Effect of Electric Field on Species Pogonomyrmex Comanche	20
10	Effect of Electric Field on Species Pogonomyrmex Barbatus	21
11	Effect of Electric Field on Species Monomorium Minimum	22
12	Effect of Electric field on Species Tetramorium Caesptum	23
13	Effect of Electric Field on Species Crematogaster Punctulata . .	24
14	Effect of Electric Field on Species Pheidole Hyatti	25
15	Effect of Electric Field on Species Forelius Foetidus	26
16	Effect of Electric Field on Species Formica Pallidefulva	27
17	Attractiveness of DC Charged Points to the Imported Fire Ant . .	28
18	Attractiveness of AC Charged Points to the Imported Fire Ant . .	29
19	Elimination of Foragers in Laboratory Colony Using an Electric Trap	32
20	Control of the Red Imported Fire Ant in Traffic Control Cabinets in College Station, Using Two Different Insecticides	35
21	Control of the Imported Fire Ant in Traffic Control Cabinets in College Station, Using Different Dosage Levels	36

LIST OF FIGURES - continued

22 Control of the Imported Fire Ant in Traffic Control Cabinets in the City of Bryan, Using Different Dosage Levels 37

23 Accumulation of Fire Ants Inside Sealed and Unsealed Relay Switches 43

LIST OF TABLES

1 Wilcoxon's Signed Ranks Tests of the Effects of Insecticidal Treatment 38

2 Partial List of Insecticide Products Containing Chlorpyrifos and Registered for Fire Ant Control 40

3 Partial List of Insecticide Products Which Would Provide Short-Term "Knockdown" of Fire Ants 41

I. INTRODUCTION

The fire ant (*Solenopsis invicta*) is native to Argentina. It was accidentally introduced into Mobile, Alabama, in the 1940's. It spread rapidly and entered Texas by 1957 (Fig. 1) where it continues to spread at an exponential rate. Control and eradication of the fire ant has met with little success. Fire ants are expected to infest much of the southern United States, being limited only by cold temperature and dry weather conditions. The 10°F minimum winter temperature depicted in Figure 1 has been suggested as the northern boundary of infestation of *Solenopsis invicta* in the United States, although the fire ant occurs outside this boundary (Lubbock, TX).

1. Research Problem

Imported fire ants, as well as numerous other ant species, are strongly attracted to electric fields. In addition, fire ants appear to be attracted to the protection from the elements offered by structures such as traffic control cabinets. This attraction results in three basic problems: (1) the ants cause short circuits in electrical equipment, (2) they interfere with the operation of electromechanical devices, and (3) they sting maintenance personnel and delay needed maintenance operations. The ants remove insulation from wires causing shorts between electric lines. In addition, they bridge contacts on terminal blocks, causing direct shorts through their bodies.

The principal operational problem is the interference caused when they enter relay switches. Fire ants accumulate in such large numbers that the switch is no longer able to function or is shorted. This causes numerous failure problems in equipment, ranging from pump motors, air conditioners, to traffic signal lights. Although this is a common and widespread problem, it has not been studied to any extent. It has been reported previously in another species. The white-footed ant, *Technomyrmex albipes* has been observed to enter relay switches in New Zealand and cause them to malfunction [1]. Termites may also attack plastic and lead-sheathed cables [2].

The fire ant is a potentially serious problem to the security and efficacy of traffic signal systems in Texas. Fire ants enter signal conduits and remove insulation from wires, causing a short circuit, resulting in an unexpected outage of the traffic signal. Fire ants are reported to have entered electrical power cable sheathing and have created a void whereby water could get inside the waterproof sheathing, causing a short which could also

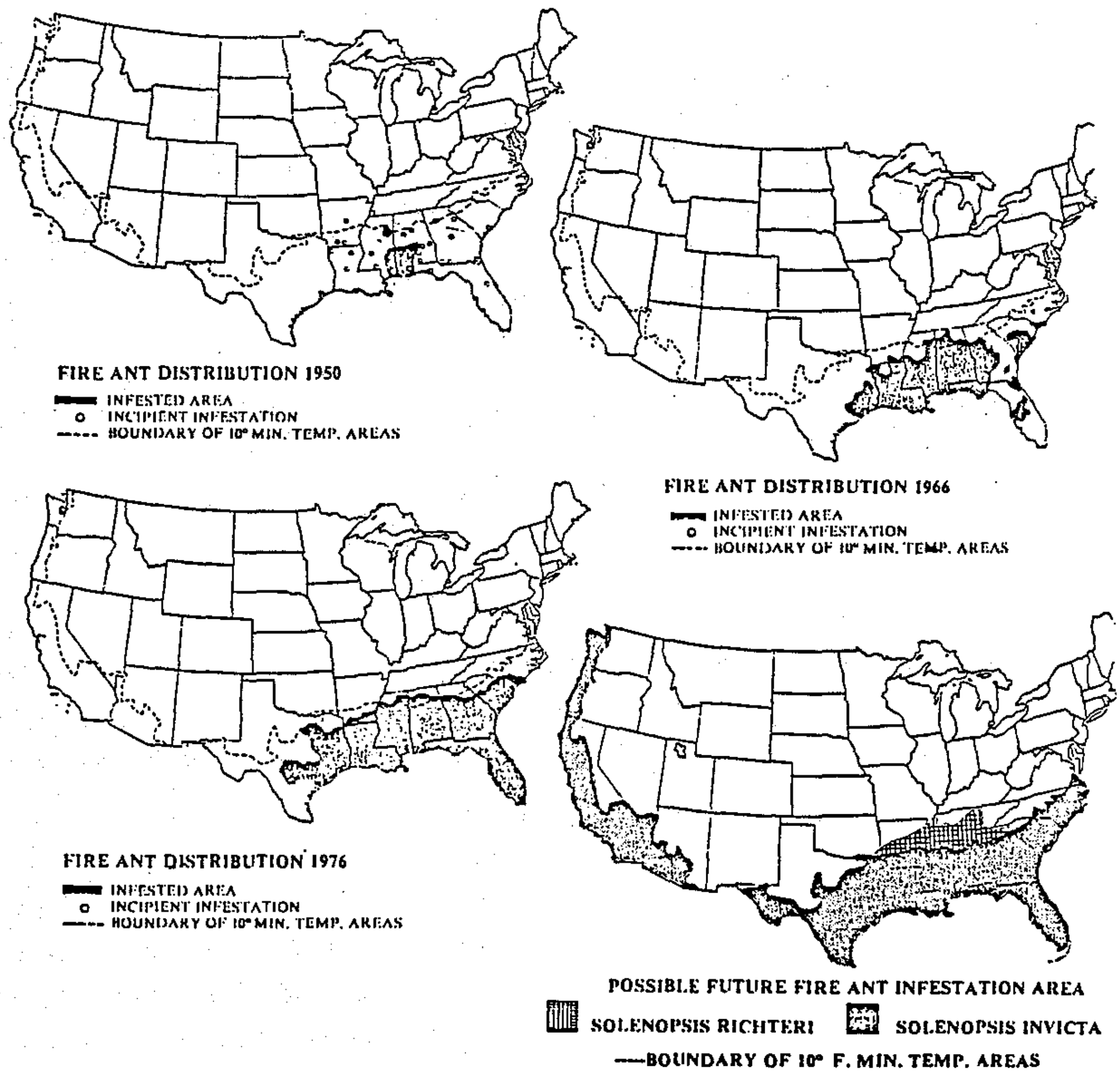


Figure 1. Fire Ant Distribution in the United States.

cause an outage of the signal. Fire ants also enter relay switches of the signal control box and cause shorts that could also knock the system out of service. In some other cases, the fire ants have caused damage by accumulating in a mass, bridging sensitive electrical switches and causing electrical circuit malfunctions. When ants invade a relay, they prevent the emergency flash operation from functioning. Regarding traffic signal and safety lighting installations, the ants are a potentially serious safety hazard in Texas and other southern states where fire ants are found.

2. Research Program

In response to the observed recent fire ant infestation of traffic signals in Texas, the State Department of Highways and Public Transportation (SDHPT) initiated and sponsored a research project entitled, "Prevention of Fire Ant Damage to Signal Control," Project 2-18-86-1135, to develop short-term and long-term solutions to fire ant infestation of traffic signal systems in Texas. In order to achieve this goal, a work plan was developed to address the fire ant infestation problem and to specify recommended treatments and practical solutions to the infestation problem.

As an immediate first step in this research to find practical solutions to the fire ant infestation problem, a field survey was conducted in six southern states, including Texas, to identify what, if anything, the other southern states' departments of transportation have done or were doing to specifically ameliorate fire ant infestation of traffic signal systems. The findings of this survey were described in project report 1135-1 [3], published in late 1986. A summary of the findings of the 1986 field survey is presented in the next section of this report to provide a complete documentation of the overall research effort.

Based on the findings of the initial field survey, a series of both laboratory and field experiments were designed to recreate conditions under which fire ant infestation was observed, and to test different types of treatment. Specifically, laboratory experiments were designed to investigate the interaction between fire ants and various electrical and magnetic phenomena, and gases. Also, field experiments were carried out in the cities of Bryan and College Station, Texas, to study the degree of effectiveness of different insecticides in reducing the impact of fire ants on traffic signal control cabinets.

This report contains a description of these experiments as well as the results and specific recommendations pertaining to cost-effective short-term and long-term solutions to the problem of fire ant infestation of traffic signal control cabinets.

II. SURVEY OF THE FIRE ANT PROBLEM IN SOUTHEASTERN UNITED STATES AND POTENTIAL SOLUTIONS

In an effort to determine the magnitude of the fire ant problem in signal control boxes and evaluate measures other states are taking to control the fire ant problem, a field trip was conducted to interview administrative and technical personnel in order to obtain the maintenance experience and current design practice of traffic and electrical engineers in addressing the fire ant problem. The following state and municipal agencies were interviewed:

State	City
Alabama Dept. of Highways	Montgomery, Alabama
Florida Dept. of Transportation	Mobile, Alabama
Georgia Dept. of Transportation	Tallahassee, Florida
Louisiana Dept. of Transportation	Jackson, Mississippi
Mississippi Dept. of Highways	College Station, Texas
Texas Dept. of Highways	Bryan, Texas

As reported in [3], all the southern states and cities contacted had some experience with fire ant infestation of traffic signal equipment. The recent experience in Texas with fire ants seems to reflect the general set of experiences noted in the survey. Fire ants had been observed in signal cabinets, either ground-mounted or pole-mounted, in flashers, relays, and electronic circuit boards. Ants removed insulation from signal cable wires exposed in the base of ground-mounted cabinets.

The survey indicated that the signal maintenance personnel generally were more aware of the extent and details of the problem than were administrators. None of the state DOT's or cities contacted felt fire ant infestation was a big problem. For example, on a small-problem, big-problem scale of 1 to 5, organizations consistently rated lightning strikes and resulting power surges a very bad (5) signal maintenance problem. Fire ants and other insect infestation usually scored a one (1), or small problem in relative terms. On the other hand, many signal technicians, particularly in the cities interviewed, considered fire ants a major pest or nuisance to routine signal inspection and maintenance activity. Some signal technicians have been severely stung by fire ants located around the pads of signal cabinets.

Based on recent Texas experiences with fire ants, several aspects of signal equipment design and maintenance practice may have diminished the magnitude of the fire ant problem experienced in the South as compared to what might be expected. These aspects will be discussed in the following sections.

1. Traffic Signal Design and Construction

While no figures were obtained, it is apparent that many DOT's signal installations have been pole and span-wire systems due to cost and high water table considerations. This type of design may reduce fire ant infestation problems compared to in-ground conduit and ground-mounted cabinet designs. However, it was evident that all organizations interviewed were moving toward the installation of a higher percentage of ground-mounted signal cabinets due to the increasing cabinet space requirements of microprocessor-based traffic signal systems. An increase in exposure of fire ant infestation is an anticipated and likely outcome.

All the DOT's interviewed placed a critical emphasis on sealing base-mounted signal cabinets. This emphasis is the result of the goals to weather-proof as well as to insect-proof the cabinets, which would include the invasion of fire ants. The following descriptive specifications obtained from two states for the design and installation of ground-mounted signal control cabinets illustrate the seal-proofing objective. One state requires that:

1. "All conduit connections to the cabinet shall be made watertight by the use of clear silicone rubber sealant."

2. "The joint between the bottom of the cabinet and the concrete base shall be sealed (inside and outside of cabinet) with a clear silicone rubber sealant."

Another state DOT has the following related specifications:

1. "Caulk around base of cabinet as required."

2. "On completion of the installation of wiring in conduit in the controller cabinet, all exposed conduit openings shall be sealed with a watertight compound."

3. "It shall be the responsibility of the contractor to install in the pole footings and base mounted controller footings, one 2-inch spare conduit for possible future use."

The last specification reflects the fact that all of the southern-state DOTs cast in-place concrete around the conduit leading into ground-mounted cabinets. No state uses a box-type gravel drain to provide conduit entry as the Texas SDHPT permits and sometimes installs in contract jobs.

The height of the signal cabinet off the ground was considered by one engineer to be worth evaluating. One state is reported to have started using 18-inch high footings on some jobs to expedite maintenance activity. No consensus was found on this point other than some reasonable height should be provided for drainage, water flooding, and ease of maintenance. Fire ants had also been found in cabinets mounted fairly high on both wood poles and steel poles. While the sample size was small, neither pole type was considered a strong repellent to fire ants should they become attracted to the contents within the cabinet. Given a reasonable height, sealing of the cabinet was strongly considered a more critical control issue to fire ant infestation.

Each state and city was asked about the types of wire and cable specifications used in their signal system designs. In most cases, samples of wire and cable in stock were also obtained. IMSA wire and cable specifications were the most frequently used source and were receiving good experience reports. The survey revealed that the IMSA wire and cable specifications were becoming the prevailing source for both aerial and in-ground applications. IMSA 51-3 loop wire and IMSA 50-2 lead-in (feeder) cable were dominant. Some Belden 8720 lead-in cable was still used, usually because of existing inventories, but reorders were more likely to be IMSA 50-2. The IMSA 50-2 feeder cable was sometimes stated to be preferred over Belden 8720 because aerial applications with Belden 8720 indicated its deterioration with extended exposure to sunlight. Apparently, ultraviolet light ages the outer insulation covering, causing cracking and brittleness.

Materials used for conduit runs between pull boxes and signal cabinets were also determined. The most trenched conduit used was Schedule 40 PVC. Some agencies used PVC except when boring or jacking under highways where steel pipe is used. Electrical power leads were usually placed in steel conduit. One state used rigid galvanized steel conduit for all signal system applications. Some agencies sealed around the conduit entry to pull boxes, but most did not. In any case, no agency selected conduit materials based on fire ant infestation problems.

Pull box designs varied over a wide range of design types. However, one state and some cities do not use pull boxes, per se. Junction convolutes with galvanized steel conduit or direct continuous wire runs were used. One state emphasized the need for water-resistant, dust-proof pull box design; whereas, most other agencies did not do so because their pull boxes were frequently filled with water. However, all agencies contacted emphasized the use of strong, waterproof splices between the loop wire and the lead-in cable. Most have approved elaborate waterproof splicing methods.

In summary, the survey found that all the agencies recommended sealing the signal cabinet at the base as tightly as possible. In no case, however, was any agency aware that any design specification or application practice of loop wire, lead-in cable, pull box design, conduit design, signal cable, or cabinet design had been made or altered to specifically repel or prevent fire ant infestation or consequences thereof.

2. Signal Maintenance

Two types of signal maintenance were noted: (1) failure-mode response and (2) routine preventive maintenance program. There was an expressed awareness of those performing maintenance of the need to conduct routine signal inspections and to perform scheduled and observed needed tasks at the signal installation. About half of the agencies contacted stated that they tried to perform routine inspections at least twice a year. One state DOT noted that some districts perform routine maintenance while others do not. Of those that performed routine, scheduled signal inspections and maintenance, a responsible traffic engineer believed that major signal problems arising from fire ants could be controlled with frequent signal inspections that would clean out infested cabinets followed by the application of effective fire ant repellents.

3. Conclusions

The survey found that fire ants are a concern to all agencies contacted, including six cities and six state departments of transportation. A wide variety of insecticides are being used. The information from this survey was used to determine the most effective strategy for controlling the imported fire ant in signal cabinets in Texas.

III. LABORATORY EXPERIMENTS

In conducting the field survey at the beginning of this research, several aspects of the fire ant infestation were observed, allowing the determination of probable causes of the attractiveness phenomenon. Based on those observations, a series of laboratory experiments were designed and carried out in the Fire Ant Laboratory of the Entomology Department on the campus of Texas A&M University. The following sections provide a description of these experiments. A discussion of the experimental results is also provided for each experiment.

1. ATTRACTION OF FIRE ANTS TO VARYING AC FREQUENCIES

A microprocessor-based controller has numerous signals that are periodic (e.g., clock and other control signals). These signals have frequencies which vary from a few hundred to several hundred thousand cycles per second. Working within that range, it was initially observed that fire ants were apparently attracted to AC frequencies of 1200 and 4800 cycles per second (Fig. 2).

The attraction aspect of this experiment was replicated five times successfully, but then no other subsequent replication of this attraction phenomenon could be obtained in the laboratory after the initial five.

As this experiment was initially successful during rainy days, it was hypothesized that relative humidity had an effect on the attractiveness of AC current to fire ants. Therefore, a new series of experiments was subsequently designed to test the validity of this hypothesis.

Under controlled environmental conditions, the same experiment was run using sealed boxes containing ants and electric wires carrying AC current. Relative humidity was manipulated using different concentrations of potassium hydroxide dissolved in water. A hygrometer and a thermometer were used to monitor relative humidity and temperature, respectively.

No significant interaction between fire ants and AC current-carrying electric wires was observed in these follow-up studies.

At this time, it is still unexplainable why the sixth and subsequent replications were not successful when the first five had shown a definite attraction of fire ants to AC frequencies of 1200 and 4800 cycles per second.

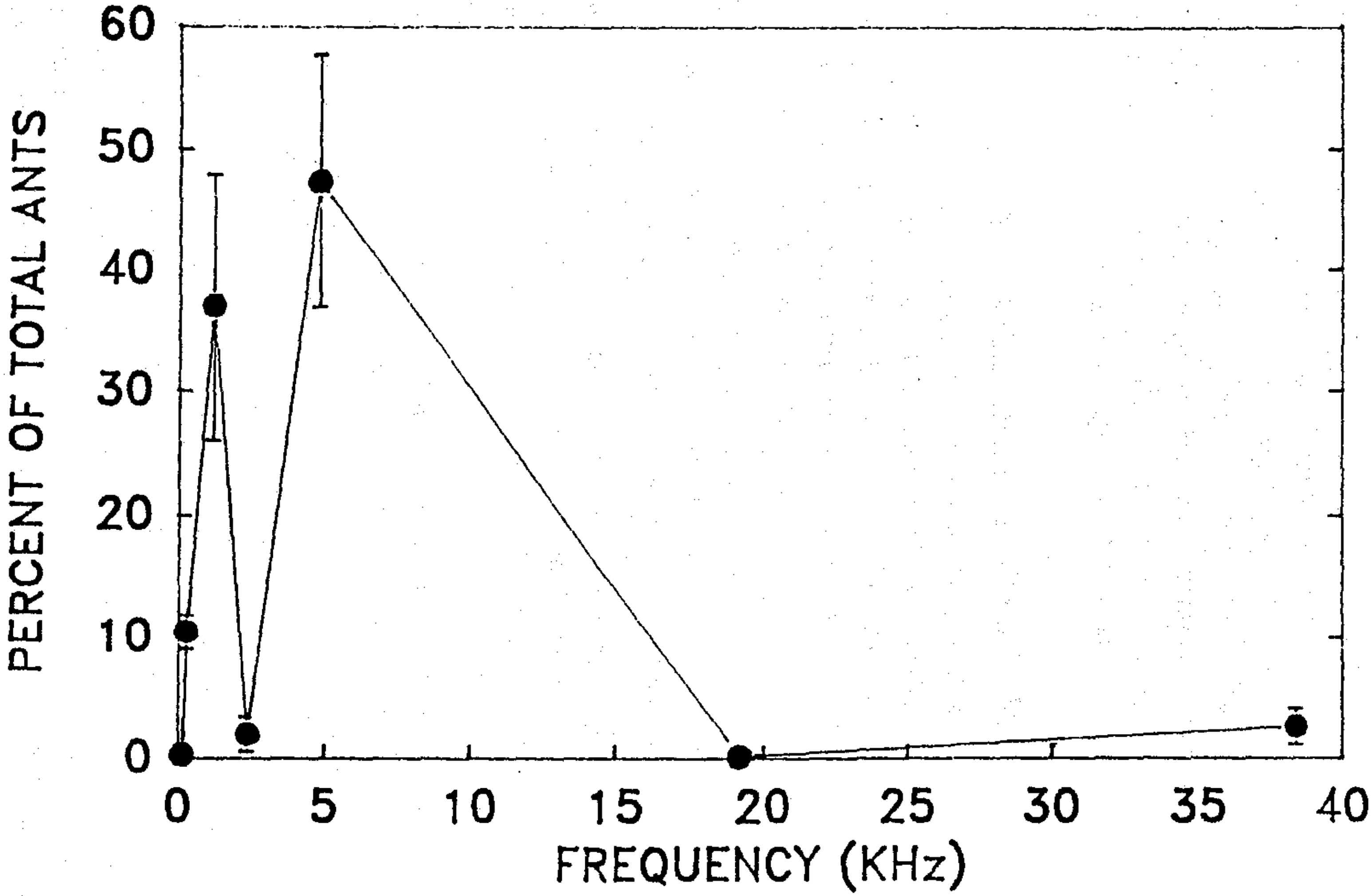


Figure 2. Attraction of Fire Ants to AC Frequencies During First Five Successful Experiments.

Needless to say, the results of this first experiment were perplexing. The initial results still suggest that the two frequencies (1200 and 4800 cycles per second) should be avoided whenever possible, as they may attract fire ants.

2. ATTRACTION OF FIRE ANTS TO RELAY SWITCHES

Highway departments have a major problem with fire ants, for they enter the relay switches in signal cabinets and short the contact points, rendering the relays inoperable. Signal cabinets have from one to eight or more relay switches, depending on the number of signal lights controlled from the cabinet.

To investigate the attractiveness of electromechanical relay switches to fire ants, two sets of six relays were designed, each with base connectors in a Plexiglas frame. Power (120 VAC, 1.89 Amps) was applied to all six relays, but only three randomly selected relays were active (i.e., switching) at a time. This test simulated actual conditions of the relays in signal cabinets. The circuitry was designed to allow random selection of active and inactive relays.

The two sets of relays were put in two different laboratory fire ant nests with observations of fire ant behavior recorded and analyzed. The relays were continuously operated in the laboratory at night (18:00 to 08:00) switching at a rate of 1 Hertz, or one cycle per second. This schedule simulated field conditions where relays are most active at night when traffic signals are normally in the flash mode. At regular intervals, the attracted fire ants were removed from the relays, counted and returned to the relays to determine the rate at which they accumulated within the electromechanical relays. Nonparametric statistical analyses were used, since none of the distributions were normal (Kolmogorov-Smirnov's one sample test), and the variances were heteroscedastic (Bartlett's test).

This experiment resulted in massive accumulations of fire ants inside the active relays (Fig. 3). Significantly more workers of the imported fire ant entered active rather than inactive relays in a laboratory setting (Wilcoxon's signed rank test, $\alpha < 0.005$). More experimentation with relay switches was carried out in the field as described in section IV-2.

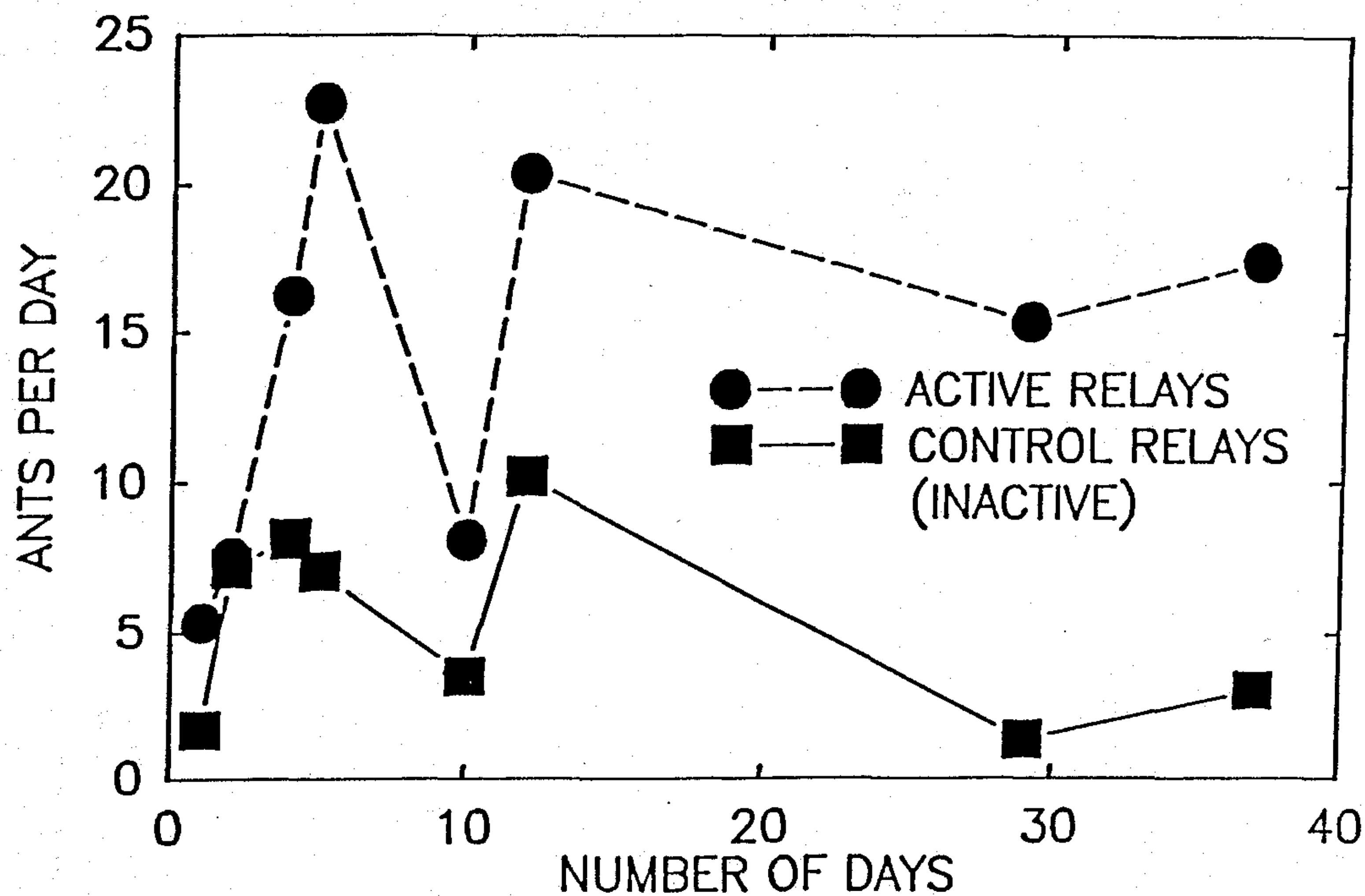


Figure 3. Laboratory Data Comparing Numbers of Imported Fire Ants in Active and Inactive Relays.

3. EFFECT OF OZONE ON FIRE ANTS

During the operation of relay switches, ozone is generated inside their plastic containers. To examine the relationship between the attractiveness of relays and ozone, an experiment was designed using an ozone generator to introduce ozone into plastic tubes carrying air.

Air flow rates were measured with a rotometer and adjusted to the following rates: 40, 60 and 100 cubic cm/min. Initially, groups of about 100 ants were placed in each of 4 chambers (2 control with no ozone, 2 with ozone in the air flow.) Equal amounts of food (fire ant formula and mealworm) were placed in each chamber with a fire ant nest placed outside the chambers.

Each time this experiment was run, the same results were obtained. The ants were equally attracted to food, whether or not there was ozone in the chamber. Ants also evacuated the chambers (with and without ozone) at the same rate. Neither an attraction nor repulsion was observed in the behavior of the fire ants in the presence of ozone. There was some fire ant mortality, but it was comparable in all chambers.

Ozone does not seem to have any effect in attracting (or repelling) fire ants into electromechanical relay switches. This was an important finding in that it eliminated a reasonable possibility and narrowed the search of viable attraction factors.

4. EFFECT OF MAGNETIC FIELDS ON ANTS

Since electromechanical relay switches have a magnetic coil as a main active component, it was decided to examine the attractive effect of magnetic fields on fire ants.

Two apparatus were prepared in which four test tubes (in each) were wrapped with 5 turns (126.4 uH, 167 ampere turns of pressure) or 10 turns (1.264 uH, 333 ampere turns of pressure) of wire (Fig. 4), respectively. Current (0 to 0.4 Amps) was applied to the wires in order to generate a magnetic field within the tubes. The numbers of ants which entered the tubes (energized and not energized) were compared in a statistical analysis.

No effect of magnetic fields (within the range tested) was observed on the behavior of fire ants. Previous experiments using a magnetic stirrer to generate a magnetic field also showed no effect of magnetic fields on fire ant behavior.

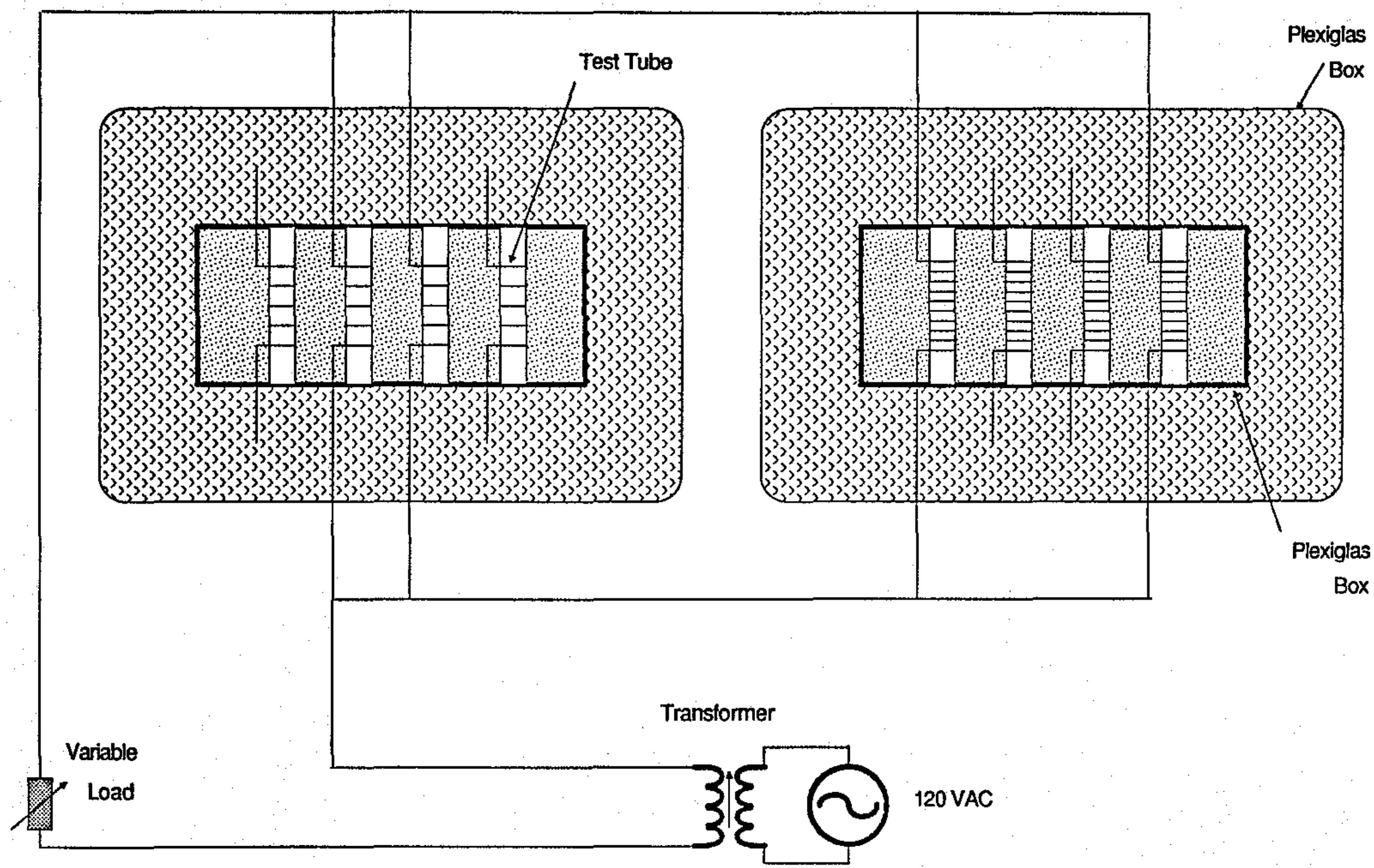


Figure 4. Apparatus Used in the Magnetic Field Experiments.

5. ATTRACTIVENESS OF ELECTRIC FIELDS TO FIRE ANTS

The hypothesis in this experiment was that fire ants would be attracted to the electric field generated between the contact points of a relay switch. Our previous studies had shown that fire ants were attracted to active electromechanical relays, but not due to magnetic fields or generated ozone.

One-centimeter diameter copper disks were cut to simulate contact points in relays. Sixteen pairs of points were placed in the bottom of a plastic box (27 cm X 39 cm) and each point had a wire soldered to the center (Figs. 5,6). Various voltage levels were applied to the points. Each pair of points was independently controlled and a wide range of voltage levels could be assigned to them with currents ranging from 0 to 0.4 amps ($C \approx 0.22$ pF, electric field strength as high as 30 KV/m).

The fire ants were strongly attracted to points with a potential differential of 10 volts DC and higher (Fig. 7). Ten different species of ants in three separate subfamilies were tested and all were found to have an attraction to electric fields (Figs. 8-17). The points become more attractive to the ants as the voltage increases. In general, ants seem to have an attraction threshold, as they don't respond to low voltage levels.

Solenopsis invicta appears to have one of the lowest thresholds. Also, *S. invicta* causes the most trouble in electrical circuits primarily because this ant species is present in higher densities in urban environments as compared to native ants.

Using the same setup, AC power was applied to the points to test the attractiveness of AC-generated electric fields (Fig. 6). There was no attraction until the electricity was turned on (Fig. 18). Within 10 minutes, the points with electricity had a mean of 13-15 ants, which remained at the points as long as the AC power was on. The control points had essentially no ants. The experiment was replicated three times on three different days with the same results. Once the power to the points was discontinued, the ants left the points, a process which took from a few minutes to 1-3 hours. With AC power, the ants left the points at a much slower rate than they did with DC power. After 3 1/2 hours, the number of ants on the contact points was observed to be essentially zero.

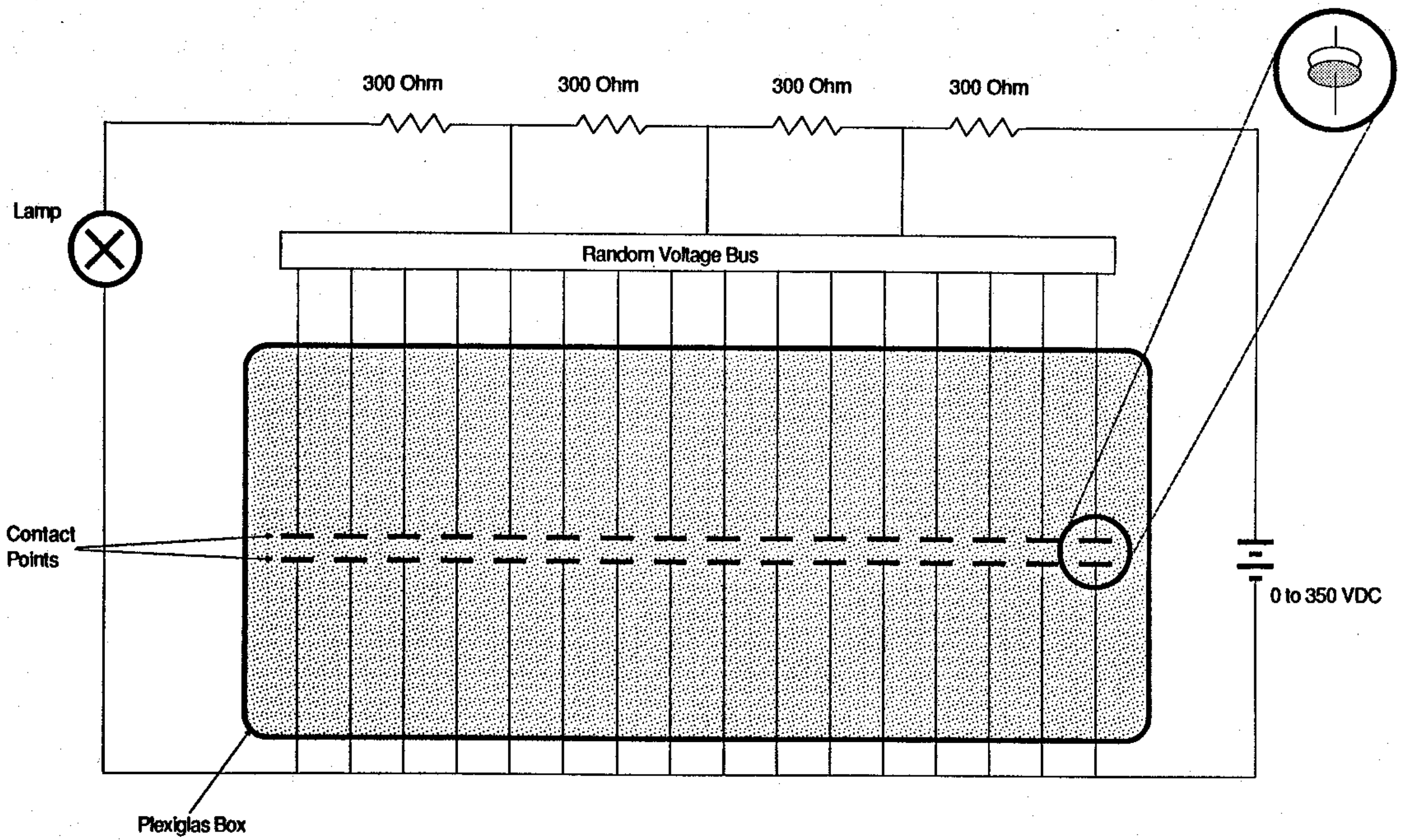


Figure 5. Apparatus Used in DC Electric Field Experiments.

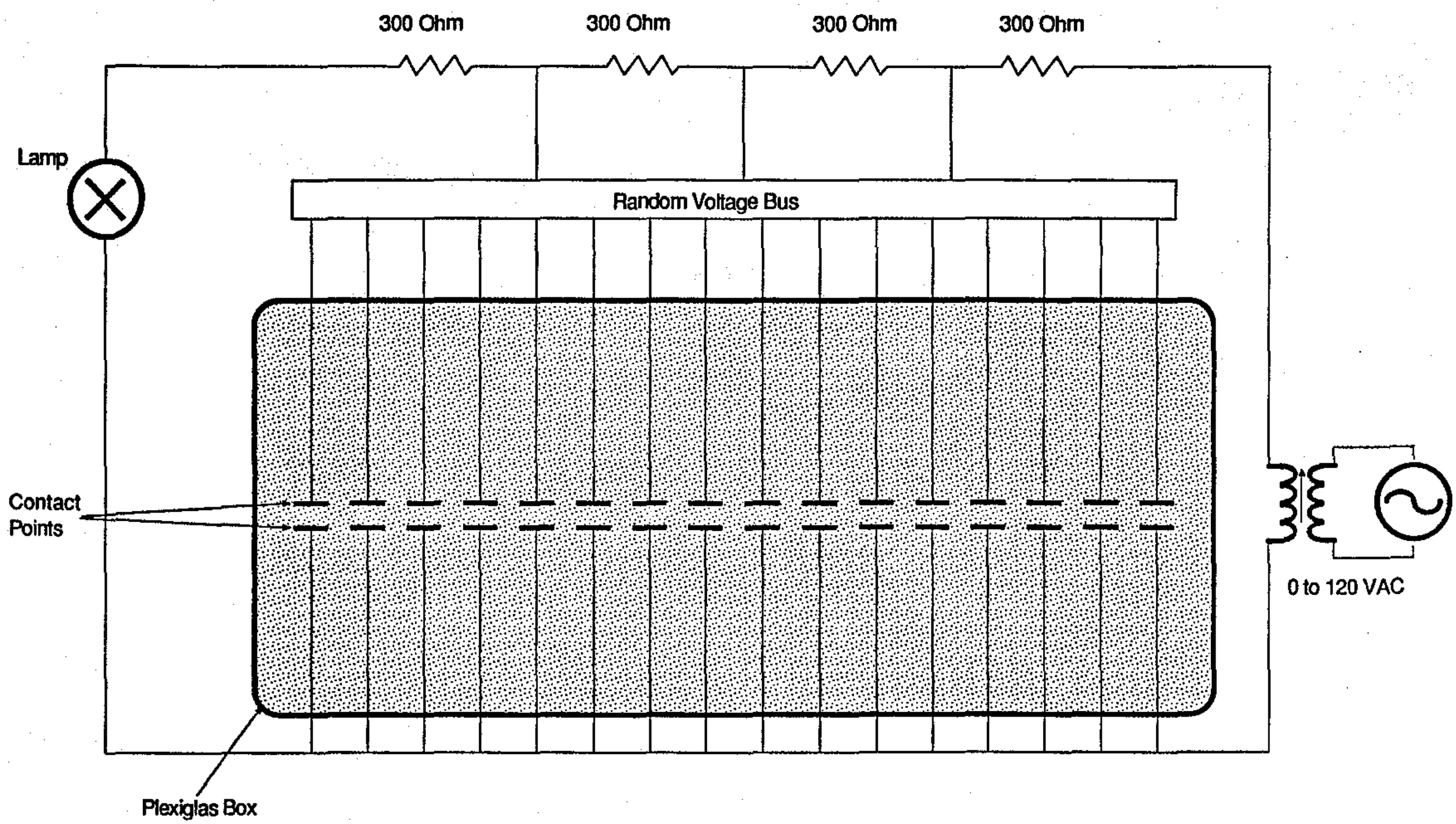


Figure 6. Appartus Used in AC Electric Field Experiments.

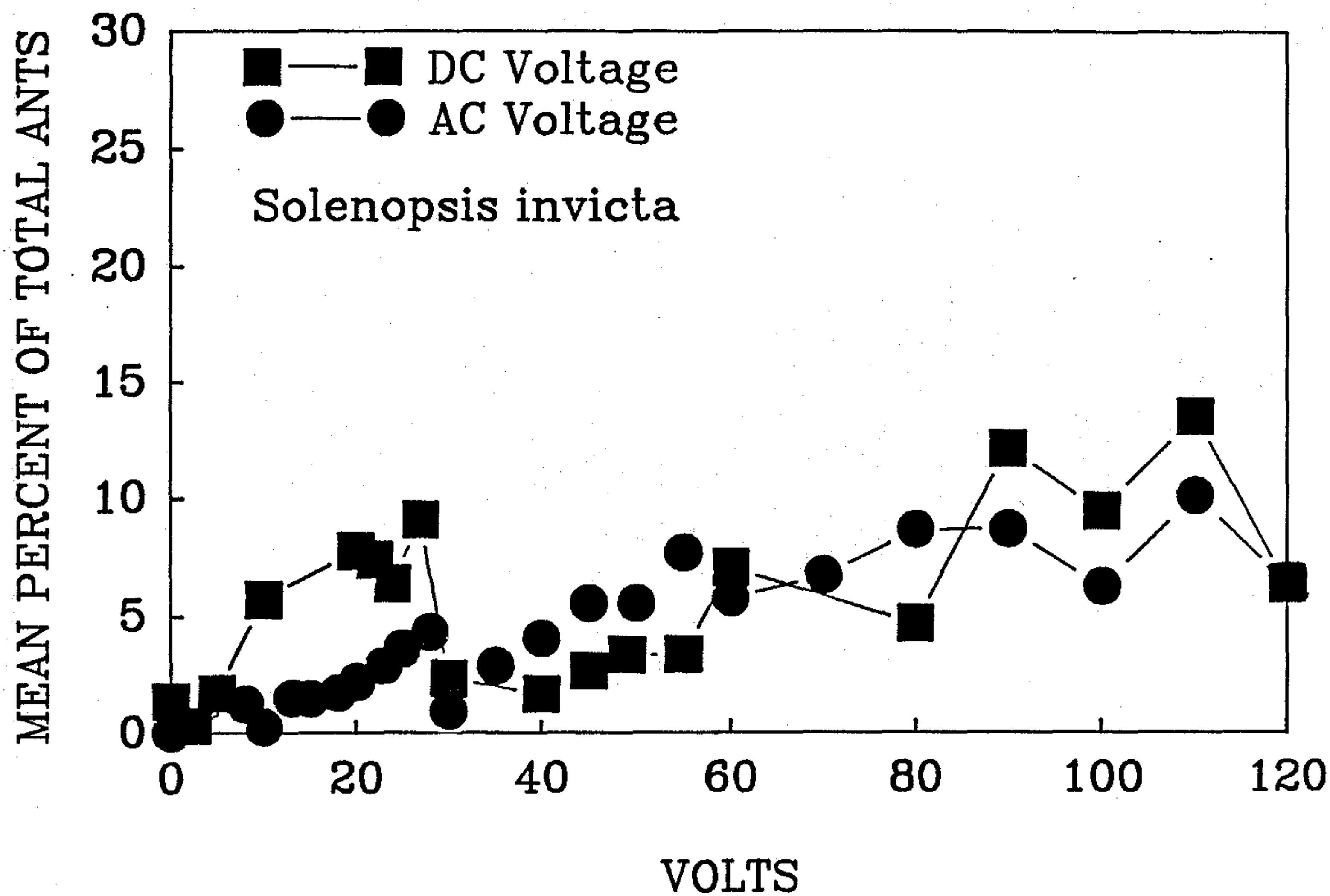


Figure 7. Effect on Electric Field on Species Sloenopsis Invicta.

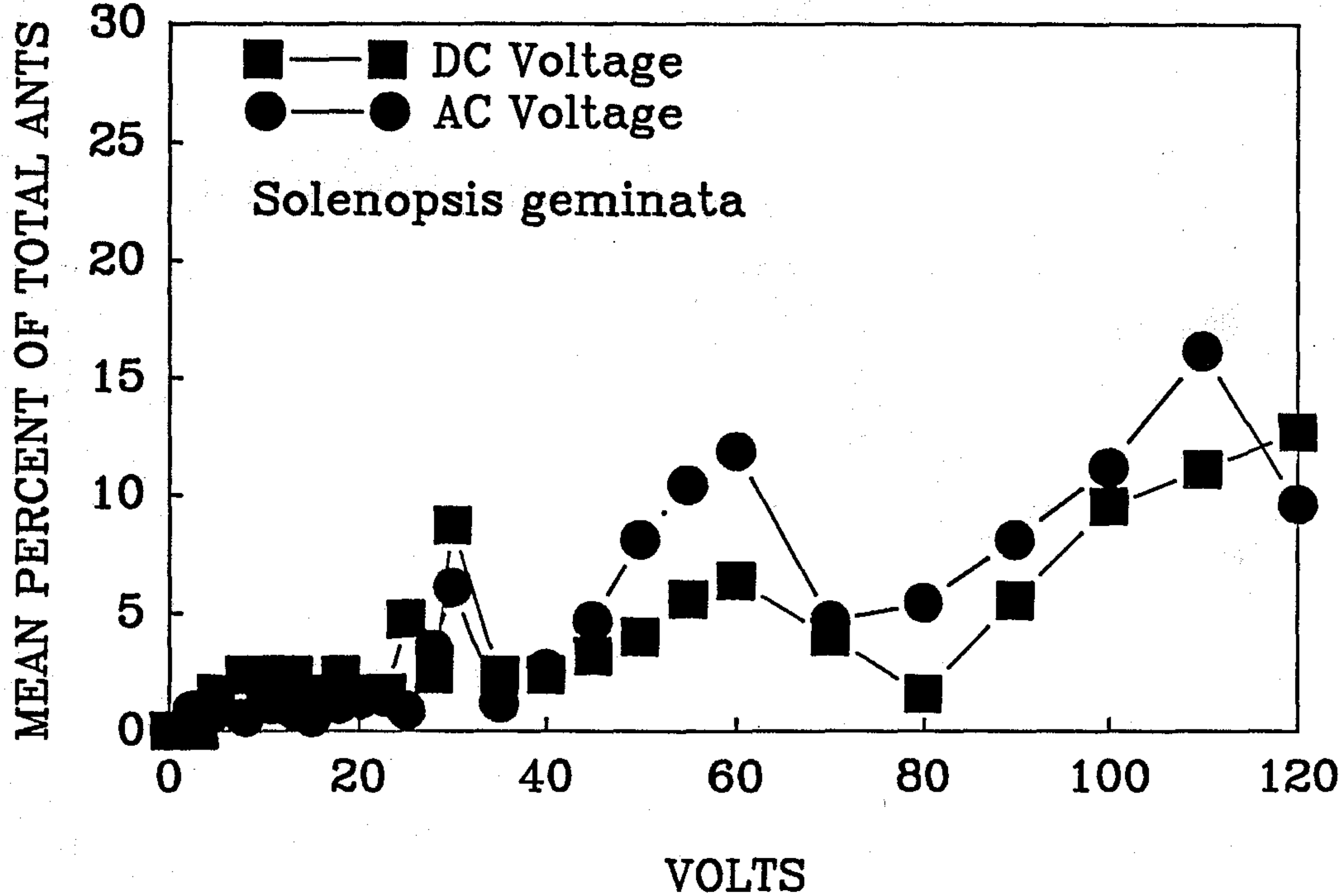


Figure 8. Effect on Electric Field on Species Solenopsis Geminata.

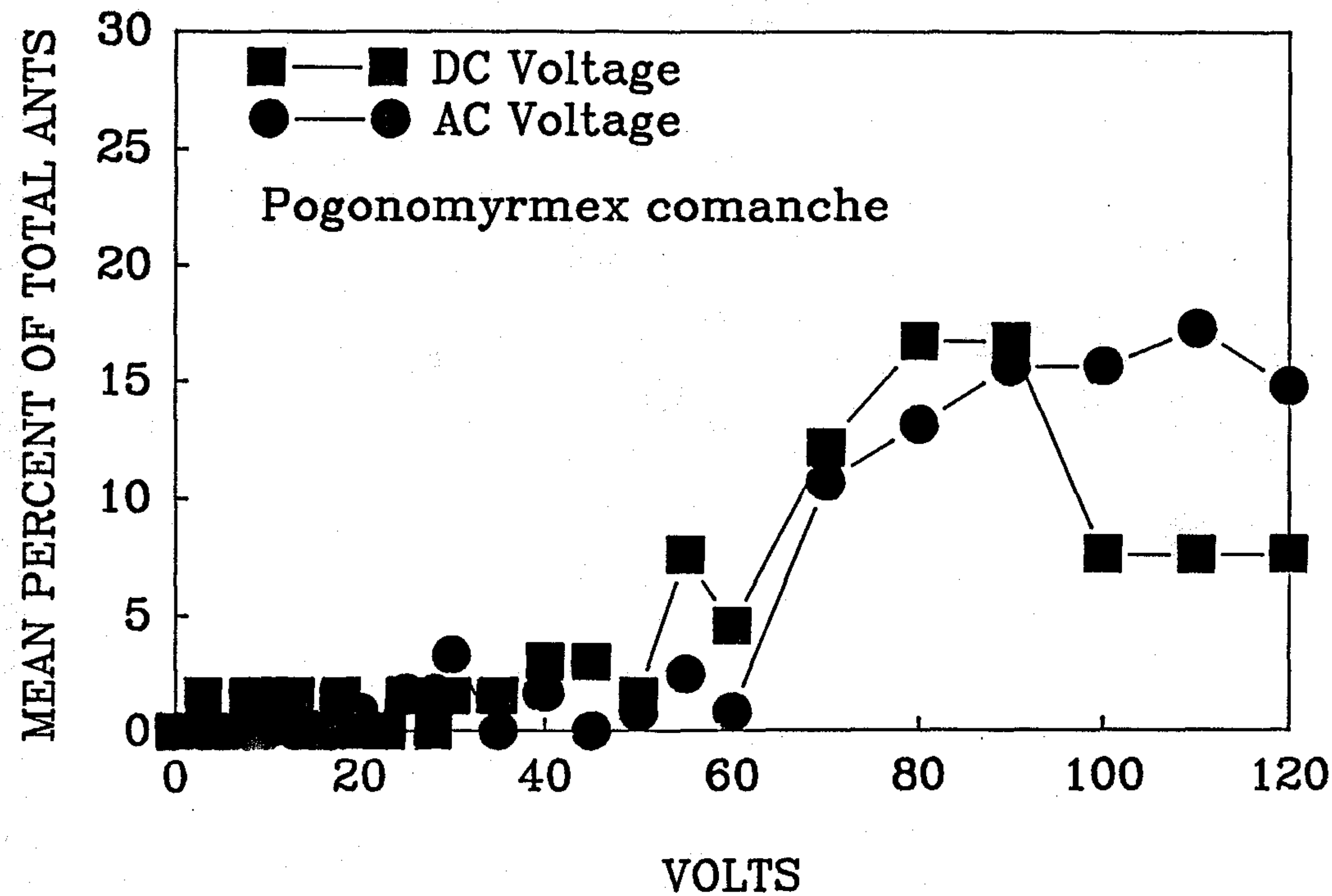


Figure 9. Effect of Electric Field on Species Pogonomyrmex Comanche.

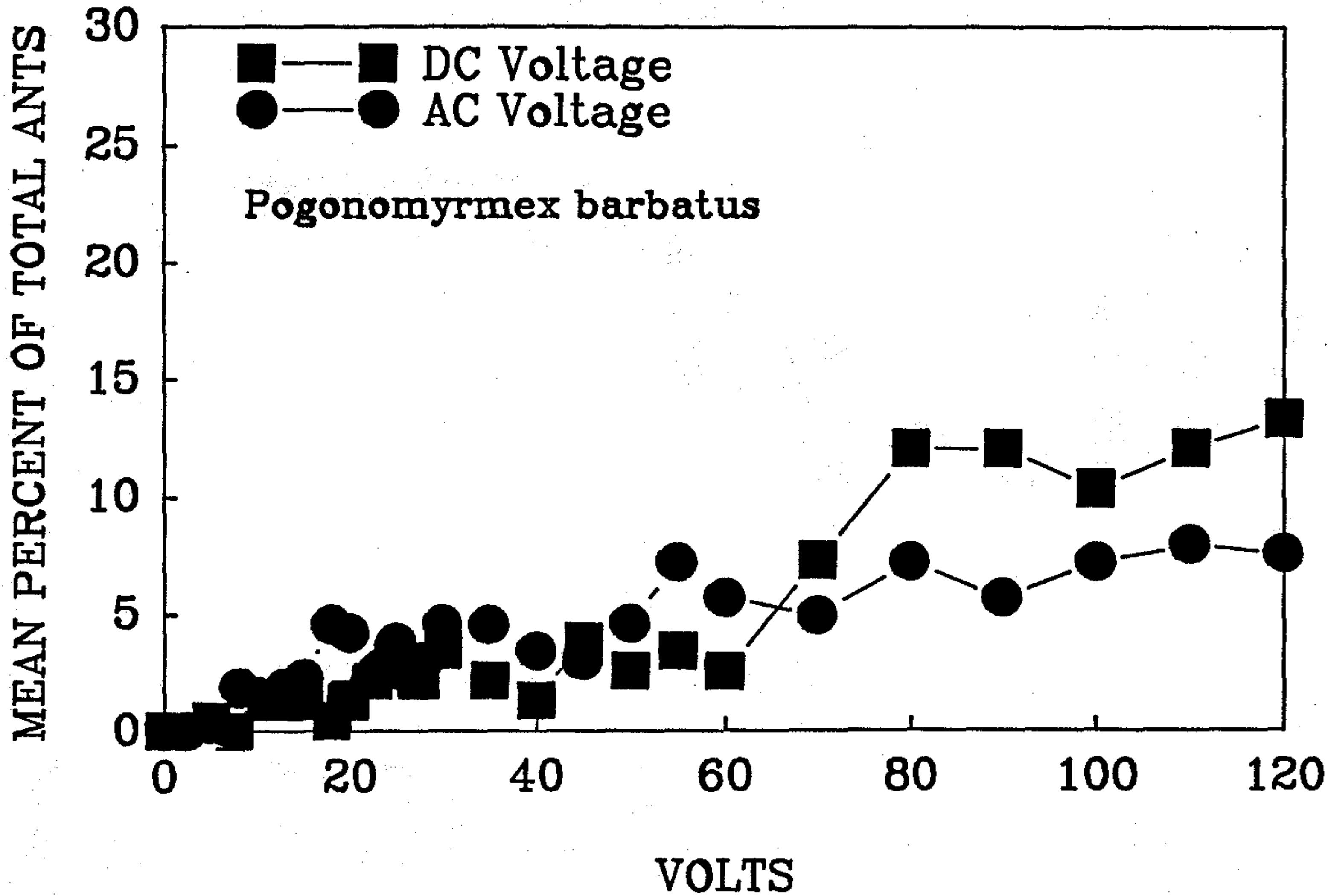


Figure 10. Effect of Electric Field on Species Pogonomyrmex Barbatus.

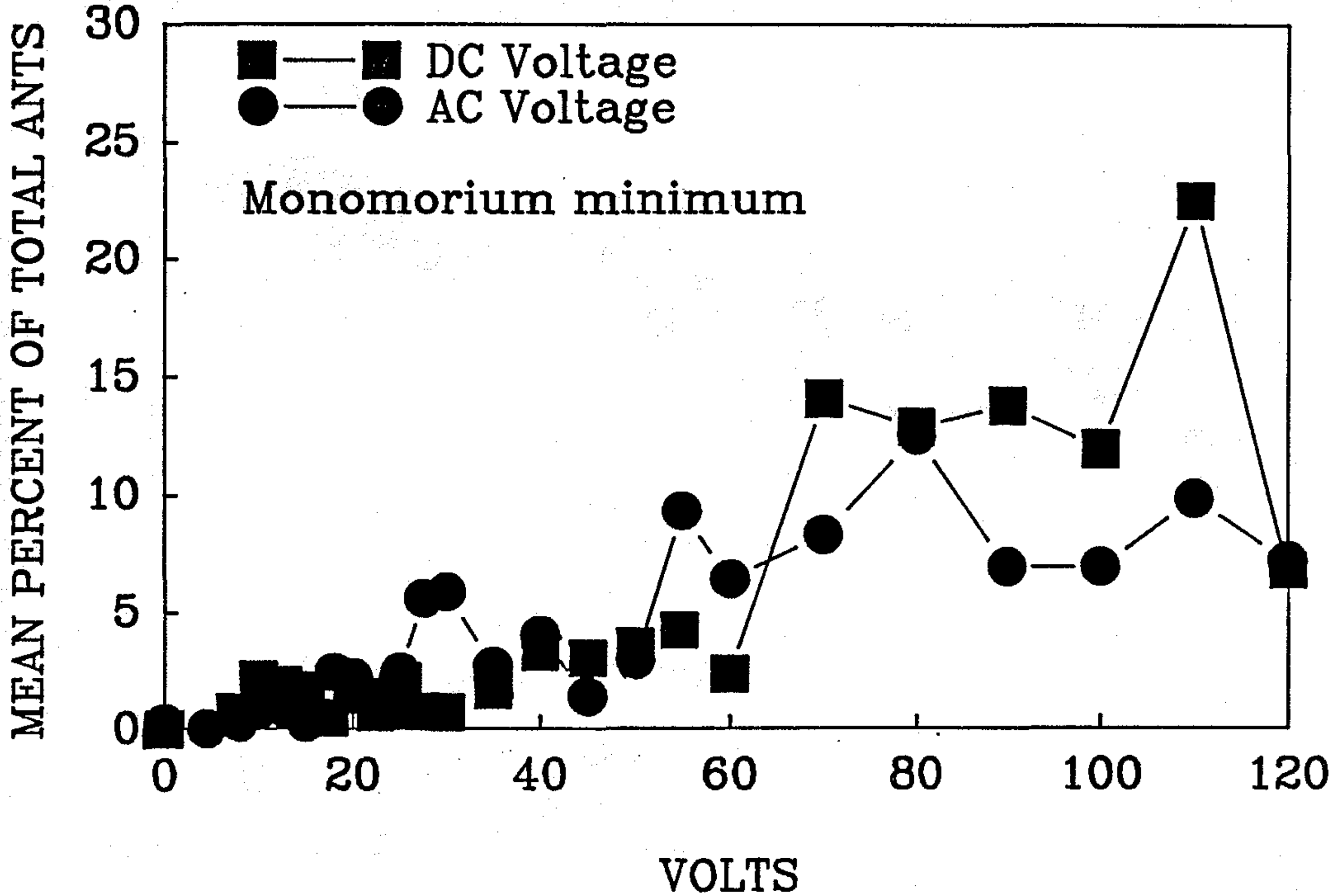


Figure 11. Effect of Electric Field on Species Monomorium Minimum.

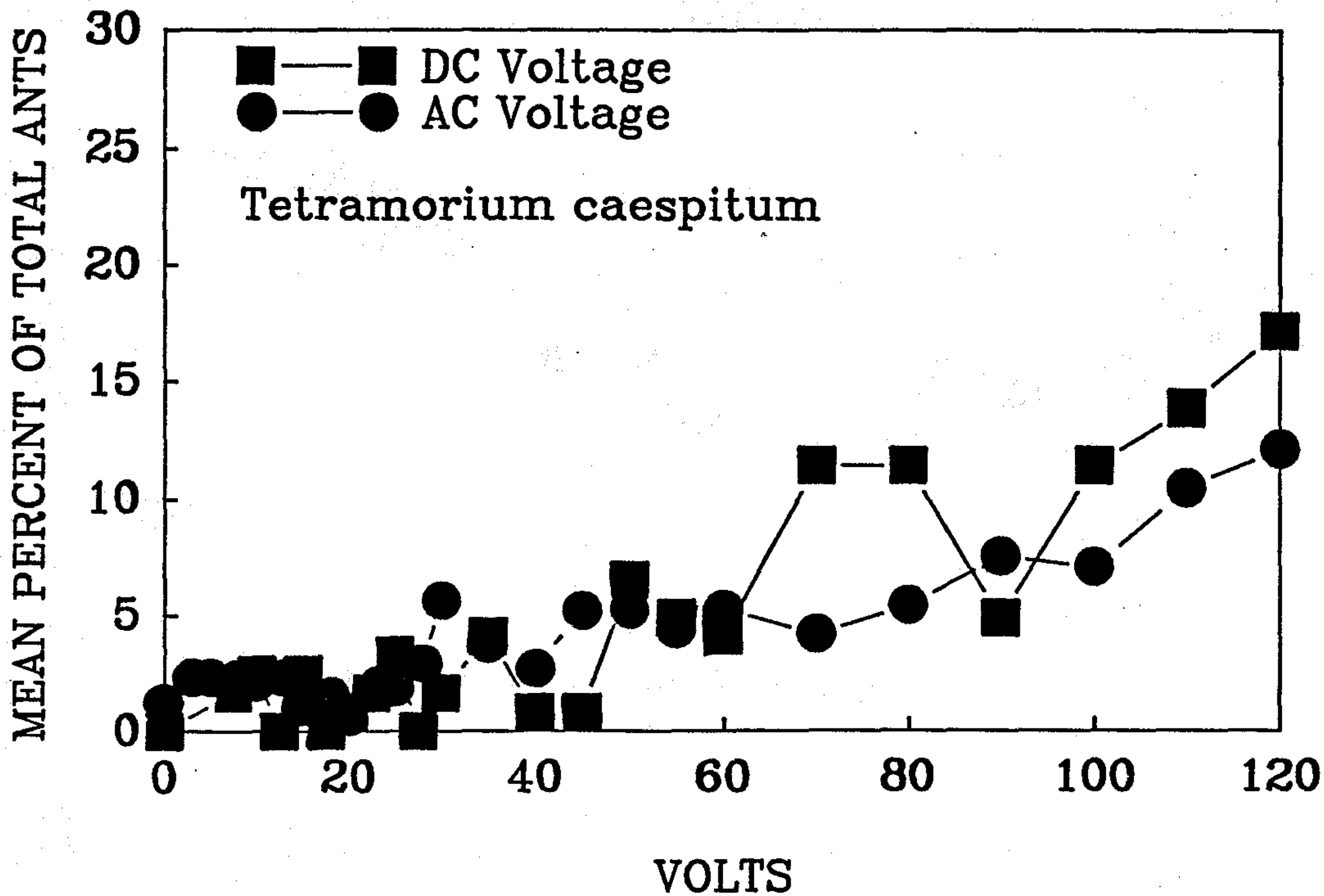


Figure 12. Effect of Electric Field on Species Tetramorium Caespitum.

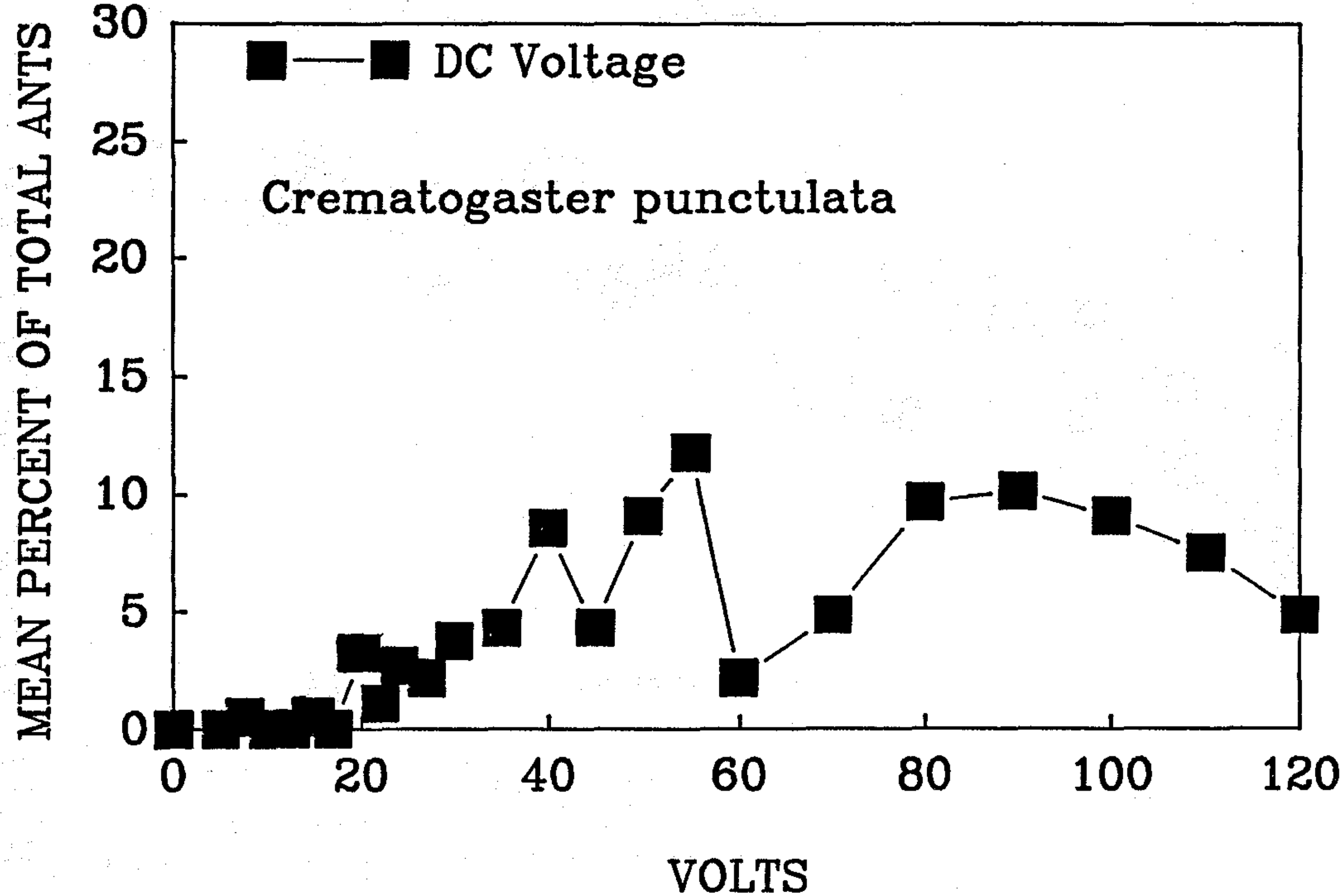


Figure 13. Effect of Electric Field on Species Crematogaster Punctulata.

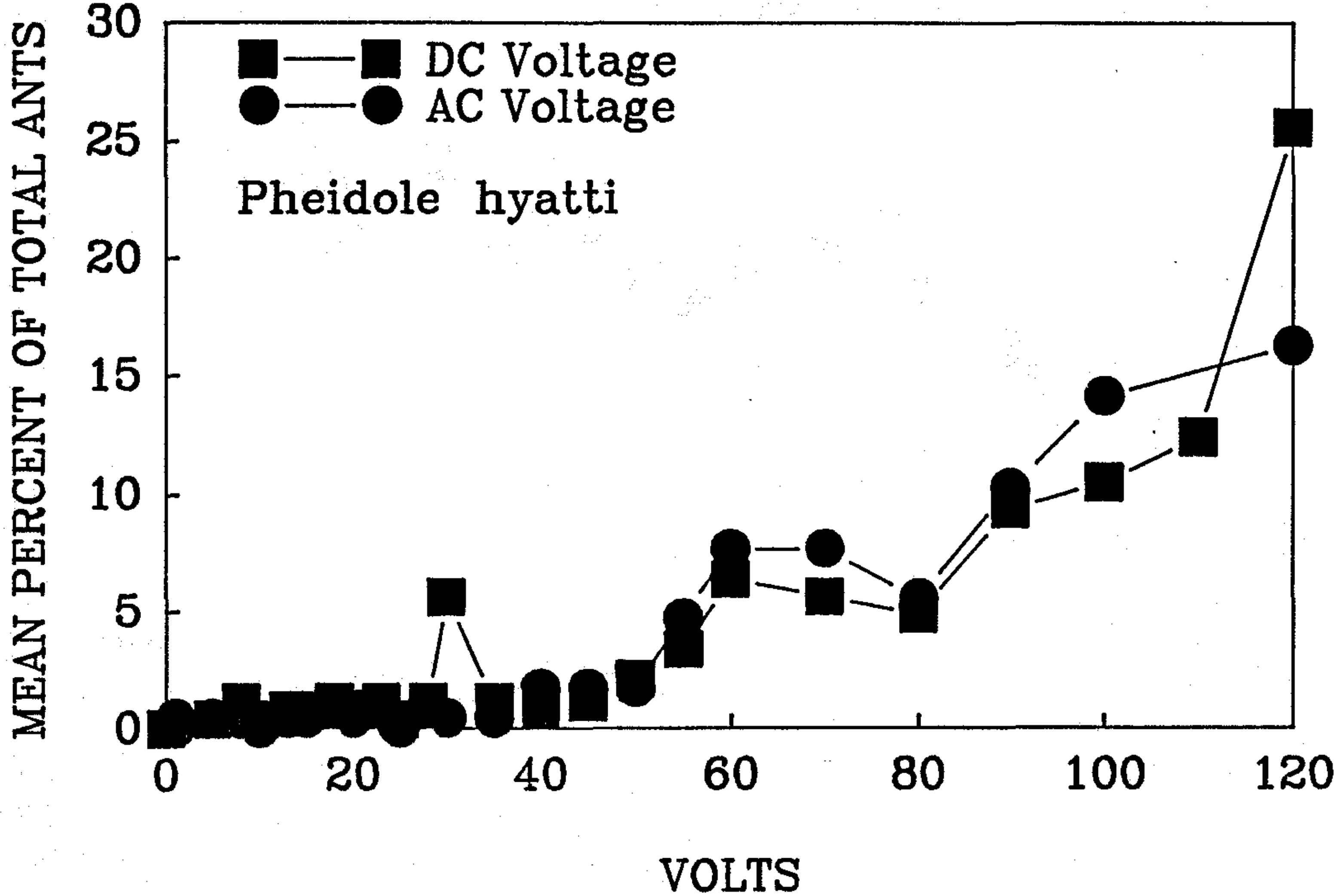


Figure 14. Effect of Electric Field on Species Pheidole Hyatti.

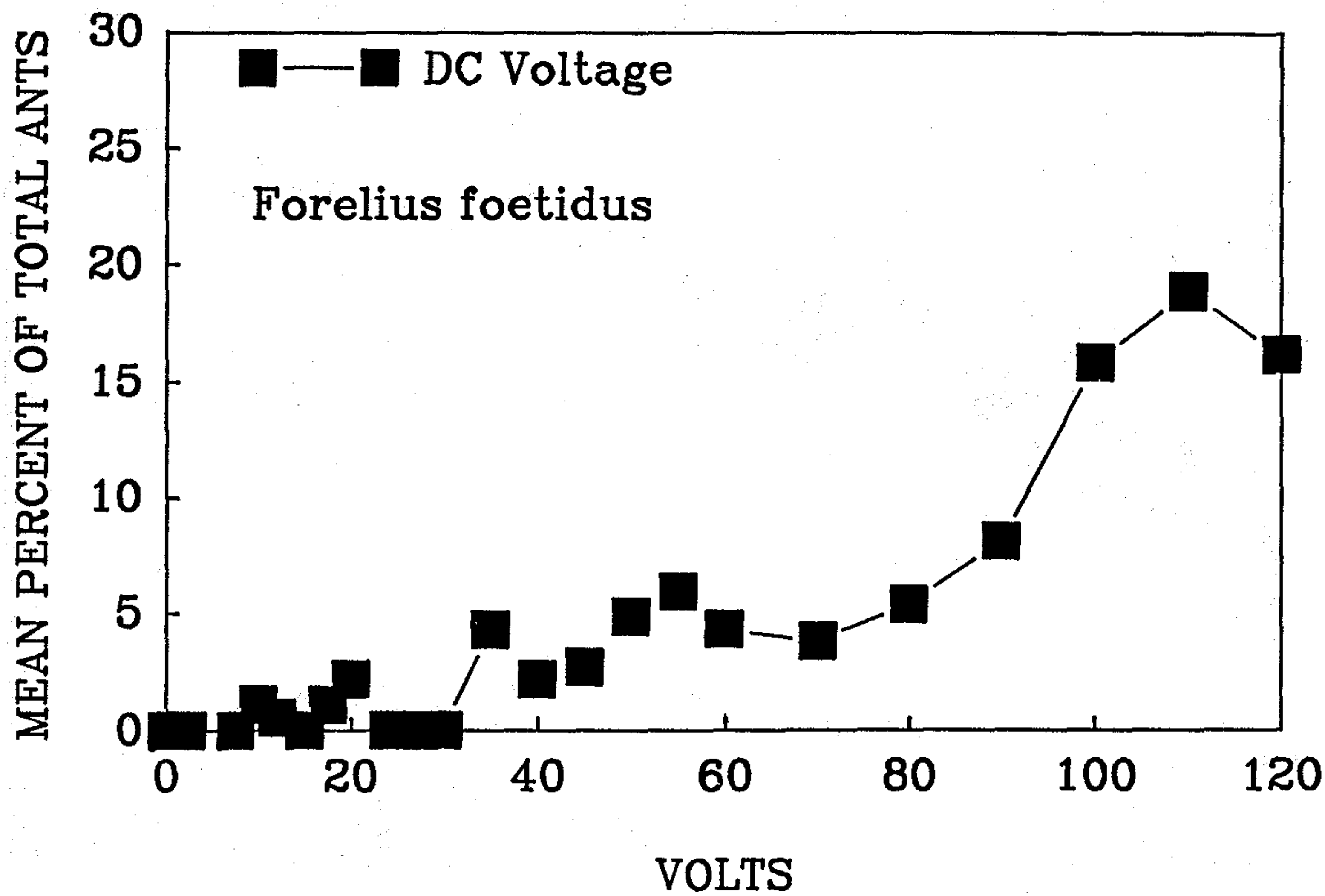


Figure 15. Effect of Electric Field on Species Forelius Foetidus.

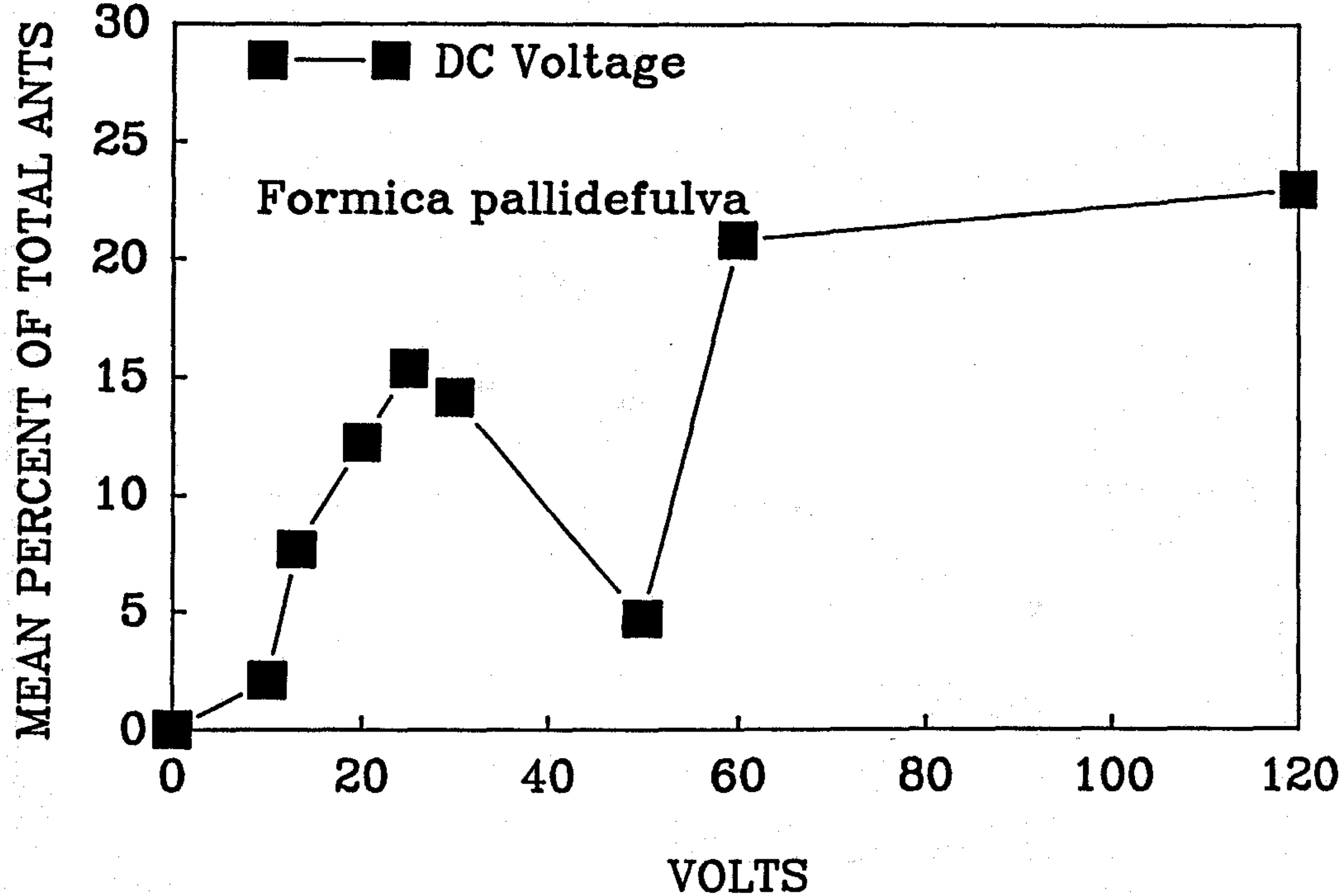


Figure 16. Effect of Electric Field on Species Formica Pallidefulva.

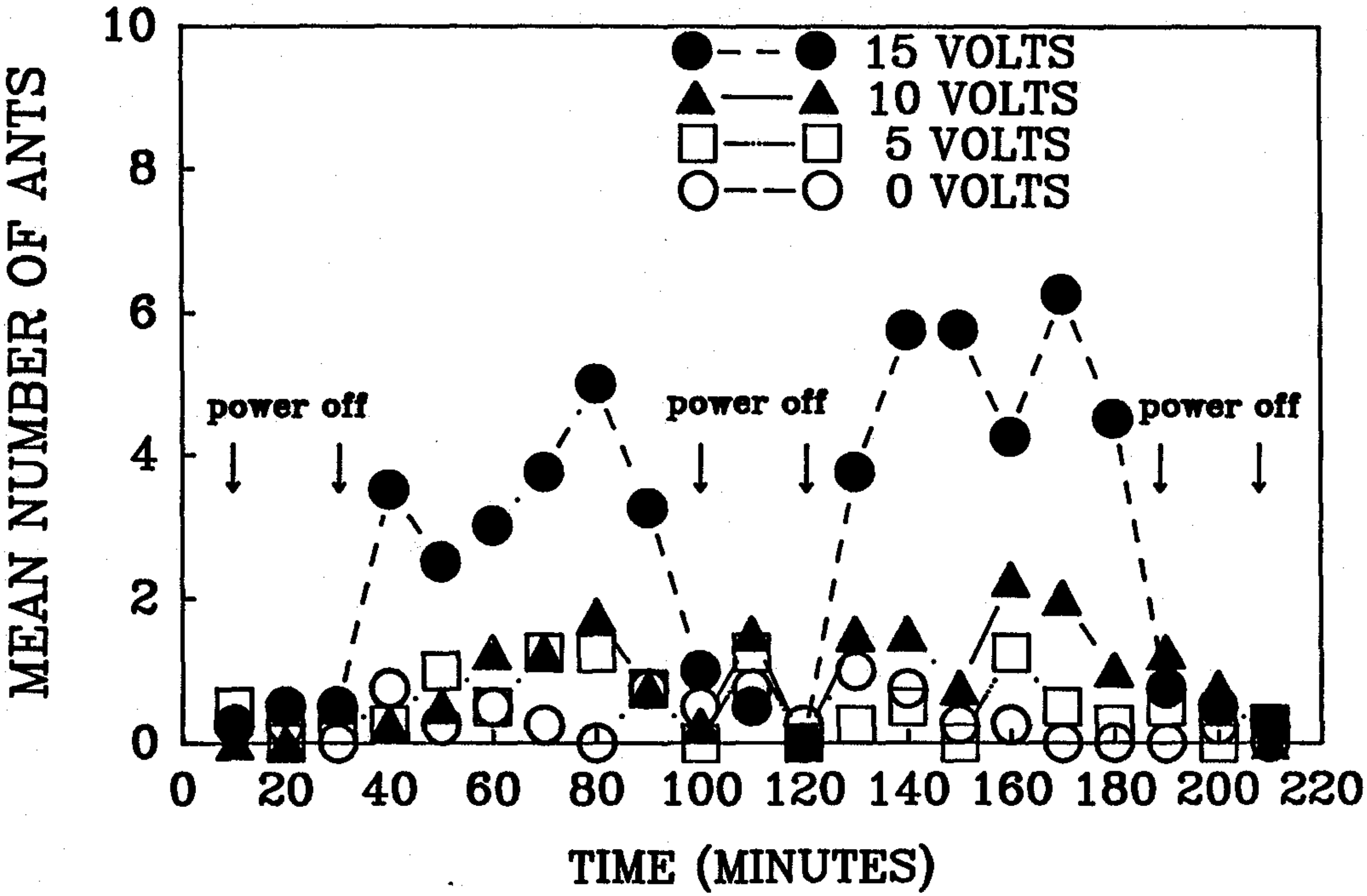


Figure 17. Attractiveness of DC Charged Points to the Imported Fire Ant.

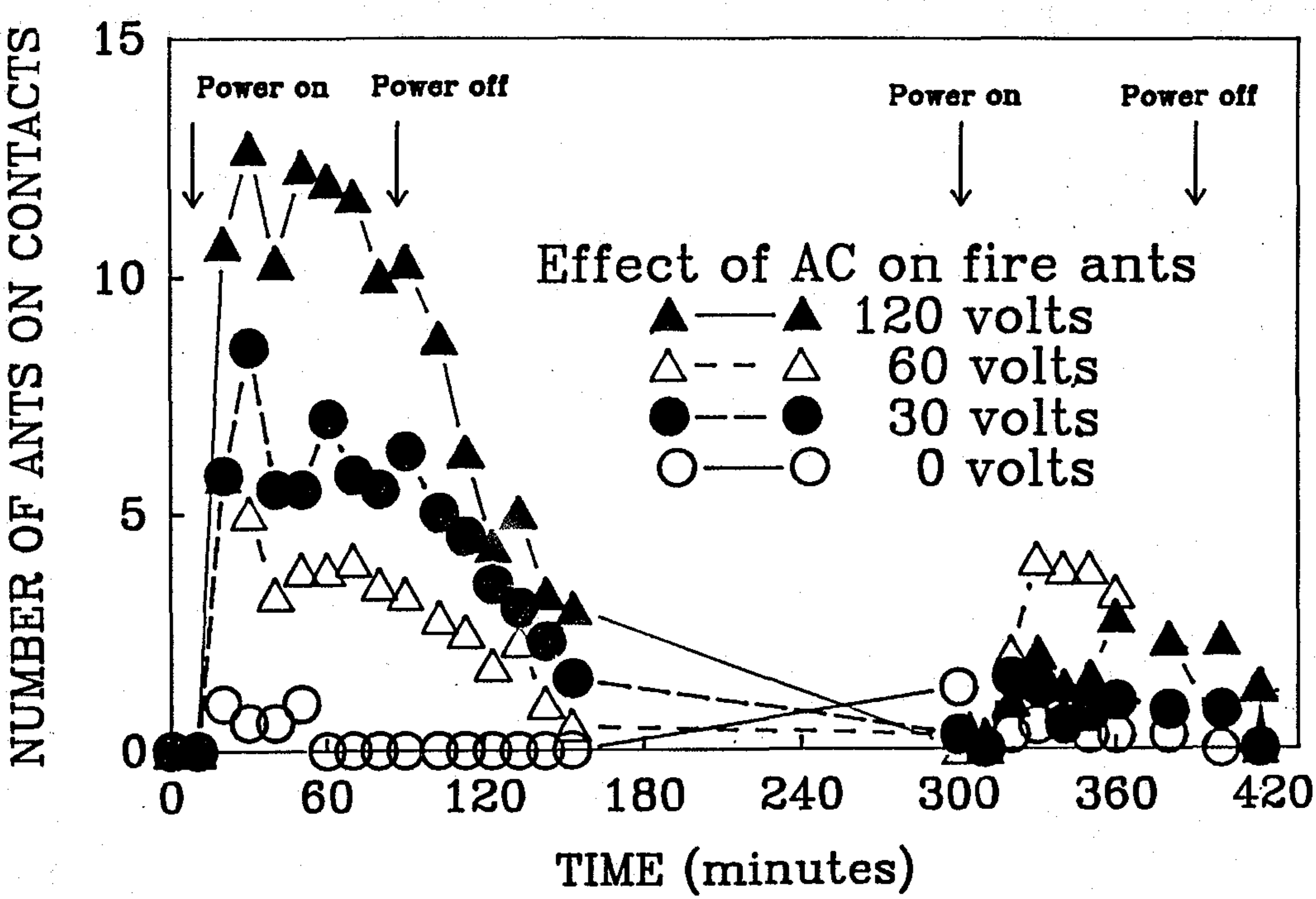


Figure 18. Attractiveness of AC Charged Points to the Imported Fire Ant.

The attraction effects of AC and DC electricity appear to be similar. When the power is off, there is no fire ant attraction to the points. Once power is turned on, the ants move to the points within minutes. The effect is higher at 120 volts than at lower voltages. The major difference between AC and DC electricity is that when the points are AC-powered, the ants take much more time before leaving the points once power has been cut. Even after an hour, many ants were still at the contact points that had been AC-powered.

6. DURABILITY OF WIRE INSULATION EXPOSED TO FIRE ANTS

Fire ants are known to have attacked wire insulation in electrical installations. To investigate this phenomenon, pieces of the following types of wire were placed in laboratory nests as well as in field colonies:

- XHHW AWG 8 (4338),
- XHHW AWG 12 (4347),
- XHHW AWG 14 (4481),
- XHHW XLP8,
- XHHW XLP AWG 6 (E11486) black insulation,
- XHHW XLP AWG 6 (E11486) white insulation, and
- XHWH AWG 8.

Wire pieces in laboratory nests were weighed at two-month intervals, those in the field were likewise weighed after one year. Electrical power was not applied to these wires.

There was no significant loss in wire mass observed, indicating that the ants did not attack the insulation on the wire, at least when not carrying a current. Wire samples in field nests were collected one year after placement in the field. Mass losses appear to be minor in both sets of samples (laboratory and field nests). There does not seem to be any material component of the insulation which attracts the ants and causes them to attack the wire.

7. ELECTRIC TRAP FOR REDUCING FIRE ANT INFESTATION PROBLEM

This experiment was based on the attractiveness of electric fields to fire ants as demonstrated in section III-5. In this experiment, an electric trap was constructed using a set of contact points mounted in a plastic (nonconductive) box. The contact points were powered from the secondary of a step-up transformer (120 to 550 VAC). When power was applied, the ants were attracted and electrocuted by the contact points.

This experiment was carried out in the laboratory and was successfully repeated several times. Figure 19 depicts the results of a typical run where a nest of 500 fire ants was used. After 18 hours from power-up, all foragers were killed.

The electric trap described above might be used in signal cabinets as it could be connected to the 120 VAC power source inside the cabinets. When electrocuted fire ants fill the box, they could be simply dumped out.

It should be noted that if the electric trap were used inside signal cabinets, it would not cause an attraction of fire ants from the outside because of the electrical shielding provided by the cabinets themselves. However, since the effect of the electric field generated by the electric trap on electronic equipment located inside signal cabinets is not fully known, field testing is recommended before using this device in field cabinets.

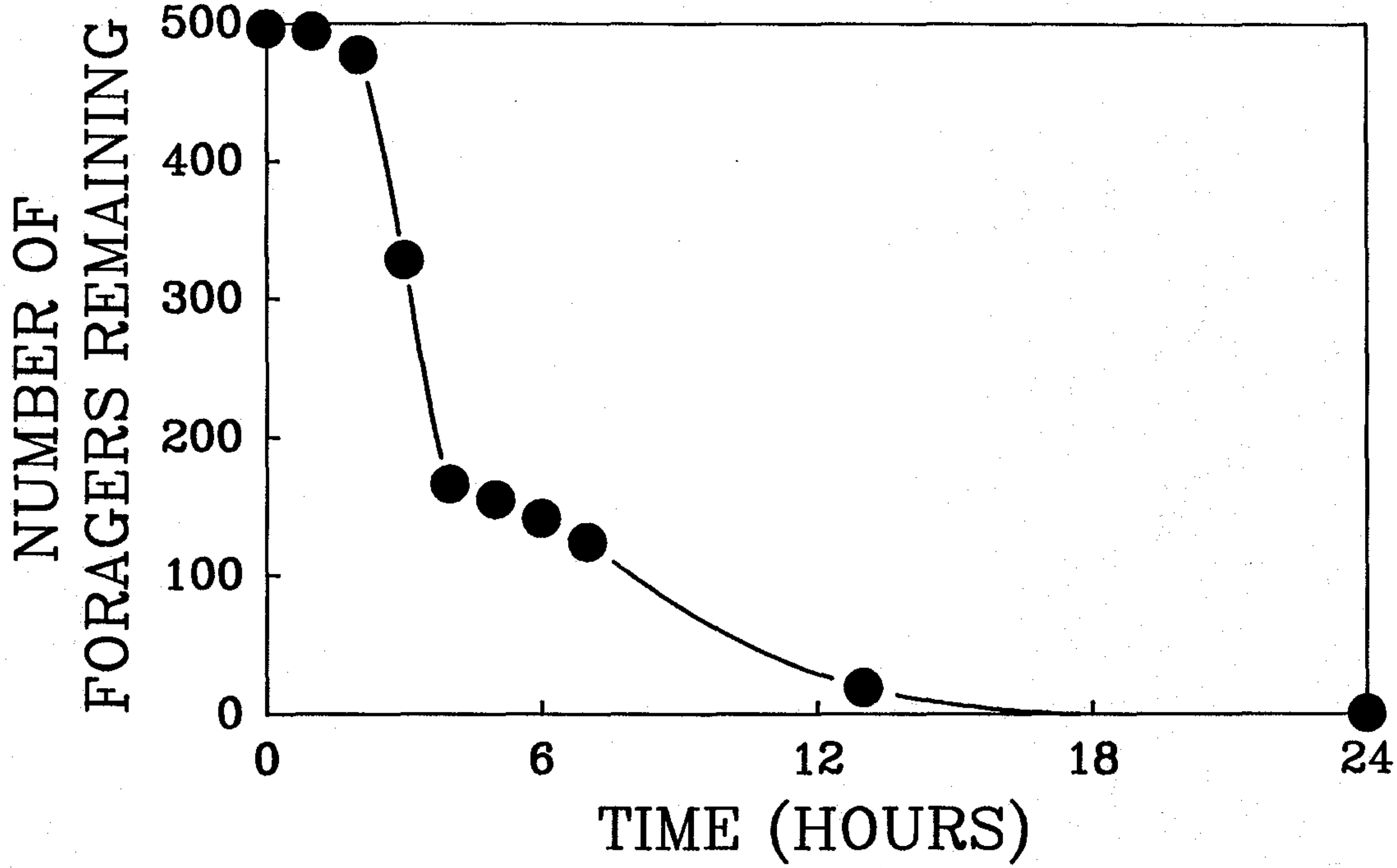


Figure 19. Elimination of Foragers in Laboratory Colony Using an Electric Trap.

IV. FIELD EXPERIMENTS

As a result of the laboratory experiments demonstrating the attractiveness of fire ants to electric fields, several treatments were devised to repel fire ants and prevent them from shorting electric apparatus in traffic signal cabinets. The following is a description of two methods that were tested in the field to achieve that goal.

1. EFFECTIVENESS OF INSECTICIDES IN CONTROLLING FIRE ANT POPULATIONS IN TRAFFIC CONTROL CABINETS

The objective of this experiment was to compare the effectiveness of four insecticides on the control of fire ants in signal cabinets and determine the minimum dosage necessary.

Fifteen cabinets in the city of Bryan and twenty cabinets in the city of College Station, Texas, were selected for treatment. Additionally, five cabinets in Bryan and ten in College Station were used as controls (not treated) for comparison purposes. This assignment was made using a table of random numbers. The cabinets used in this experiment were somewhat variable in size. The base area ranged from 0.21 m^2 to 0.76 m^2. However, most cabinets had a standard 0.65 m^2 base area. Each of the cabinets is mounted on a portland cement concrete pad slightly larger than the base of the cabinet itself. Wire cables from sensing elements in the street and to traffic lights are carried through conduits in holes made in the bottom of the concrete pad or through PVC pipes embedded in the pad.

The cabinets in College Station had not been previously treated with any product except the occasional use of 1,1,1 trichloroethane, which is not very effective. However, the cabinets in Bryan had been previously treated with a product containing 1% pyrethrin whenever ants were noticed by signal technicians to be causing problems. This treatment is judged to not be very effective in the long term.

The insecticidal treatment program began in College Station and expanded into Bryan. In the city of College Station, two treatments were experimentally applied, after the cabinets had been cleaned. The first treatment consisted of the use of a product containing 0.5% chlorpyrifos in a corncob grit, and the second consisted of the use of a product containing 0.1% pyrethrin. Chlorpyrifos was applied at 1/3, 2/3 and at the level recommended (3 oz./sq. ft. or 915 g/m^2) by the manufacturer (5 cabinets/level).

Additional cabinets (five) were treated with pyrethrin (1%). The material was sprayed on the bottom, inside the cabinet, until a uniform white covering resulted. The cabinets in Bryan were also treated in a similar manner with three dosage levels of chlorpyrifos (5 cabinets/level). The cabinets were monitored at monthly intervals.

Three other cabinets in College Station were treated with 1,1,1 trichloroethane whenever fire ant populations increased to the point they were causing problems in the circuitry. This is the most common response of signal technicians in the area.

Insecticidal treatment with chlorpyrifos were observed to significantly reduced the ant populations in College Station (Figs. 20 & 21). In the city of Bryan, the ant populations in the treatment and control cabinets were not significantly different (Fig. 22). This result was apparently because the ant populations in the control cabinets were low throughout the experiment.

The results of the statistical analysis are shown in Table 1 where a threshold of $\alpha = 0.05$ (i.e., 5%) was used to accept or reject the hypotheses. Ant populations, level of insecticide and date were compared to establish the effectiveness of the insecticidal treatment in the cabinets.

A comparison of the population levels in the treated cabinets in Bryan before and after treatment, started on May 10, 1988, did demonstrate a statistically significant reduction in the populations ($\alpha = 0.022$, Wilcoxon's signed ranks test). Thus, we can conclude that the treatment of the cabinets with chlorpyrifos controlled ant populations in both cities.

Orthogonal comparisons and Newman-Keuls multiple comparison tests showed that the treatment levels (i.e., 1/3, 2/3 and 3/3) were not significantly different in controlling ant populations in the cabinets in either city; however, ant populations were significantly lower in the treated cabinets when compared to the control cabinets.

It is clearly demonstrated that chlorpyrifos treatments are very effective, even at reduced dosages. This insecticide destroyed all of the ants in cabinets within three hours, and its potency persisted for an entire year when used at the manufacturer's suggested dosage.

Applications where chlorpyrifos products would become wet would result in reduced effectiveness (due to decomposition by fungi) and in contamination of

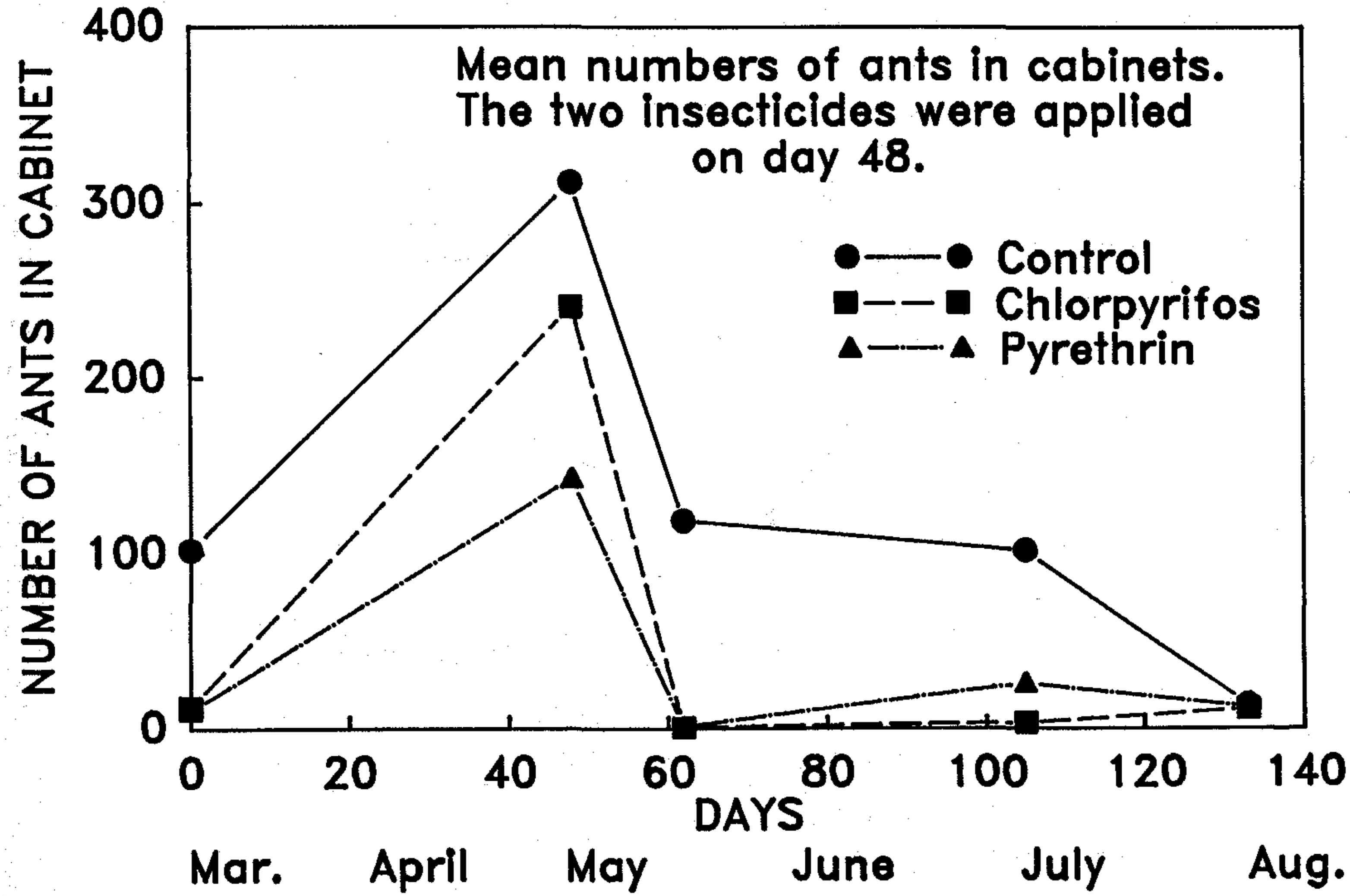


Figure 20. Control of the Red Imported Fire Ant in Traffic Control Cabinets in College Station, Using Two Different Insecticides.

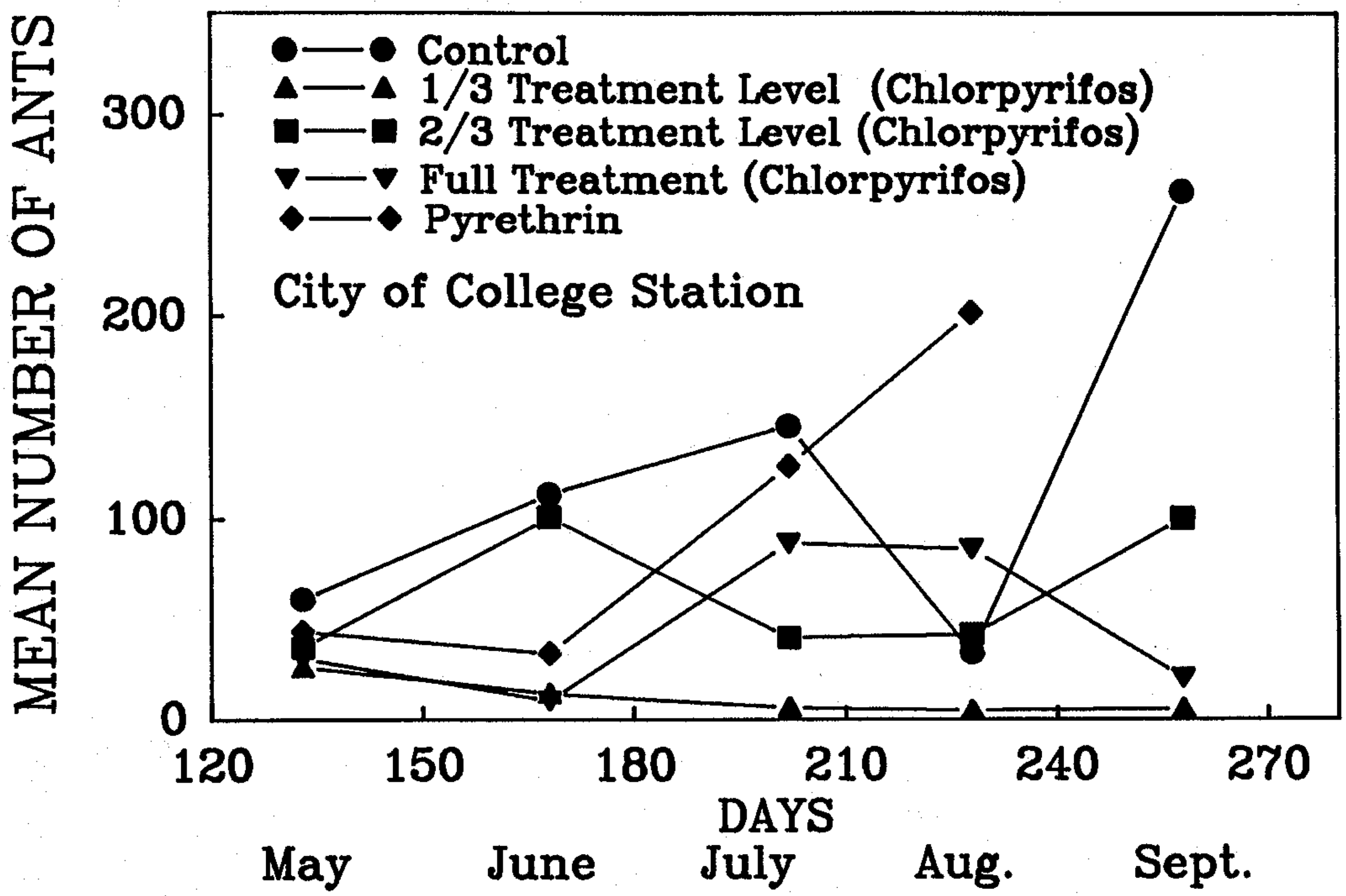


Figure 21. Control of the Imported Fire Ant in Traffic Control Cabinets in College Station, Using Different Dosage Levels.

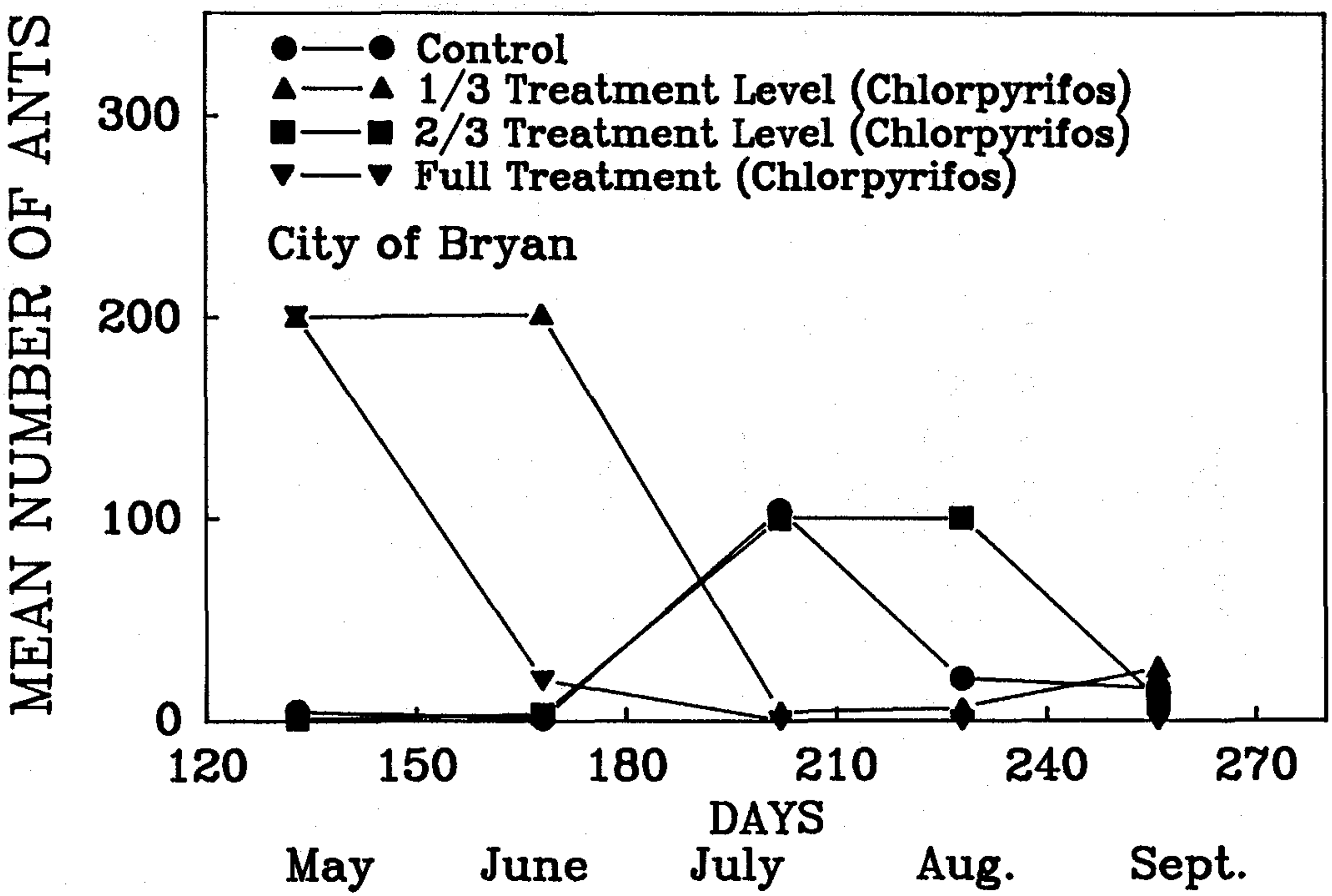


Figure 22. Control of the Imported Fire Ant in Traffic Control Cabinets in the City of Bryan, Using Different Dosage Levels.

Table 1. Wilcoxon's Signed Ranks Tests of the Effects of Insecticidal Treatment.

ALPHA LEVELS

COLLEGE STATION	ANTS	LEVEL OF INSECTICIDE	DATE
ANTS	1.000		
LEVEL	0.002	1.000	
DATE	0.001	1.000	1.000

ALPHA LEVELS

BRYAN	ANTS	LEVEL OF INSECTICIDE	DATE
ANTS	1.000		
LEVEL	0.159	1.000	
DATE	0.198	1.000	1.000

the environment. Chlorpyrifos may be effective in some areas, but not in others if environmental conditions are significantly different. Thus, further experimentation may be necessary to enable the use of the procedures developed within this research project in other locations and with other equipment.

Several insecticides containing 0.5% chlorpyrifos are available for long-term fire ant control (Table 2), manufactured and marketed by companies such as Green Light, Kenco, Rainbow Manufacturing Company, and Whitmire. Products containing a higher percentage of chlorpyrifos (Table 2) may have an equal or greater effectiveness, but they were not tested in this study. The price of the products containing a higher percentage of chlorpyrifos would be expected to be higher. Effectiveness of these products would probably not extend into the second year and thus make the added cost questionable. In addition, the disposal of the used insecticide may be more difficult, due to the higher initial concentration. The other insecticides were not observed to be as effective as chlorpyrifos over an extended period of time. Pyrethrin (0.1%) was not very effective (Fig. 21) and ultimately one cabinet had to be treated with chlorpyrifos due to the ineffectiveness of the product. Insecticide based on 1,1,1 trichloroethane was observed in the field to rapidly kill fire ants, but the treated cabinets generally would be reinfested the following day.

Many insecticides (Table 3) would be useful for the rapid "knockdown" of ants before work could be done on a heavily infested cabinet. Chemical 1,1,1 trichloroethane is perhaps the most used, but the hornet and wasp killers could also be used for wasp and native bee nests found in the cabinets.

2. PREVENTING FIRE ANTS FROM ENTERING RELAY SWITCHES

The electromechanical relay used in traffic signal control cabinets is enclosed in a clear plastic box. The pins of the relay come out through a black plastic base. In section III-3, it was clearly shown that fire ants are attracted to the relay switches. Although the experiment was carried out under laboratory conditions, the results were similar to what was happening in the traffic control cabinets. The fire ants were observed to enter relays and accumulate until the relays became inoperable. This caused a malfunction, and required sending a crew to replace the damaged relay switches and reset the controller to normal operation.

The sealed relays were first tested in laboratory nests, then in the field under actual conditions.

Table 2. Partial List of Insecticide Products Containing Chlorpyrifos, and Registered for Fire Ant Control.

Company Name	Product Name	Use*	% Active Ingredient
Black Flag	Fire Ant Killer Concentrate	1	1.0%
Cessco	Accudose Aerosol®	3	1.0%
Dexol	Fire Ant Killer	1	6.7%
	Dexa-Klor Soil Insect Spray	1	6.7%
	Dexa-Klor Insect Spray	1	6.7%
Dow Chemicals USA	Dursban® 50W	4	50.0%
	Dursban® 2E	1	22.4%
	Dursban® 4E	1	44.4%
ESCO	End-A-Bug® Fire Ant Killer	1	6.7%
	End-A-Bug® Lawn Granules	2	1.0%
Ferti-Lome	Fire Ant Killer Mound Drench	1	6.7%
	Dursban® Fire Ant 10% Granular Insecticide	2,4	10.0%
Ford's	Fire Ant Concentrate	1	5.4%
	Dursban® 1E	1	12.6%
	Fire Ant 2.5G Insecticide	2	2.5%
	Dursban® Fire Ant 10% Granular Insecticide	2	10.0%
Green Light	Double Dursban® Granules	2	10.0%
	Fire Ant Killer Granules	2	0.5%
	Fire Ant Killer	1	6.27%
	Fire Ant Mound Drench	1	0.1%
Hi-Yield	Fire Ant Killer	1	6.7%
S. C. Johnson	Raid® Fire Ant Killer	1	6.7%
Kenco	Rid-A-Bug® Fire Ant Killer	1	0.5%
Ortho	Fire Ant Control	1	5.3%
	Lawn Insect Spray	1	5.3%
	Ortho-Klor® Soil Insect and Termite Killer	1	12.6%
Rainbow Manufacturing Co.	Insect Control	2	0.5%
Rigo	Dursban® Lawn and Ornamental Insect Spray	1	22.4%
Staffel's	Ant Granules	2,4	1.0%
Starbar	Fire Ant Killer	1	6.7%
Vaporette	Fire Ant Killer Concentrate	1	6.7%
Whitmire	PT 270 Dursban®	3	0.5%
Zoecon	Strike®	1	6.7%

* 1 = mound drench
2 = granule
3 = injectable into mound
4 = broadcast

Table 3. Partial List of Insecticide Products for Short-Term "Knockdown" of Fire Ants.

Company Name	Product Name	Active Ingredients (%)
Bengal Chemical Co.	Fire Ant Killer	1,1,1 trichloroethane or methyl chloroform (96.75%)
Banner Labs Inc.	MC96 Fire Ant Killer	Methyl chloroform (96.00%)
Chevron-Ortho	Hornet and Wasp Killer	2-(1-methylethoxy) phenol methylcarbamate (0.50%)
d-Con	d-Con Bug Killer	Resmethrin (0.250%)
Johnson Wax	Raid Wasp and Hornet Killer	Tetramethrin (0.252%), O-isopropoxyphenyl methylcarbamate (0.475%)
Rampart Industries	MC96	Methyl chloroform (96.00%)

To prevent fire ants from entering relay switches, several types of sealants were tested:

-Silicon sealants:
1. Duncan 25-year siliconized acrylic caulk.
2. Duncan all-purpose adhesive and caulk.

-Epoxy cements:
1. Duncan 5-minute.
2. Plastic Steal.

The process of sealing the relays consisted of applying silicon sealant or epoxy cement to the area around the base of the relays and to the base of the protruding pins inside as well as outside of the containing box. One relay manufacturer contacted indicated that electromechanical relays for traffic signals could be readily sealed during the manufacturing process if so requested by specification.

Two cabinets were in the flash mode throughout the summer (relay switches active at all times). One of these was randomly selected to be treated with the chlorpyrifos-based insecticide chlorpyrifos (Section IV-1), the other was randomly selected to be the control cabinet. These cabinets were the only two which were continuously in the flash mode in College Station.

Three additional cabinets (not in the flash mode) were randomly selected: one was treated with chlorpyrifos, the second was used as control, the third was equipped with epoxy-sealed relays.

Each of the cabinets had three relay switches. The relays in the control cabinet in flash mode accumulated large numbers of ants (Fig. 23), significantly more than the control cabinet used for comparison (Wilcoxon's signed rank test, $\alpha < 0.05$). The treated cabinet had statistically equal numbers of ants in the active relays, as did the cabinet with sealed relays and the cabinets which were not in flash mode. Obviously active relays accumulate ants at faster rates in both laboratory experiments and under actual field conditions. Additionally, the treatment of a cabinet with chlorpyrifos effectively reduced the numbers of ants which enter the relays to levels similar to those of relays that were not active.

Epoxy was much more effective than any of the other sealants tested. No ants have entered any of the relays that were sealed with epoxy, either in field experiments or lab experiments. Relays sealed with the other products and tested in laboratory nests accumulate hundreds or thousands of ants within a month.

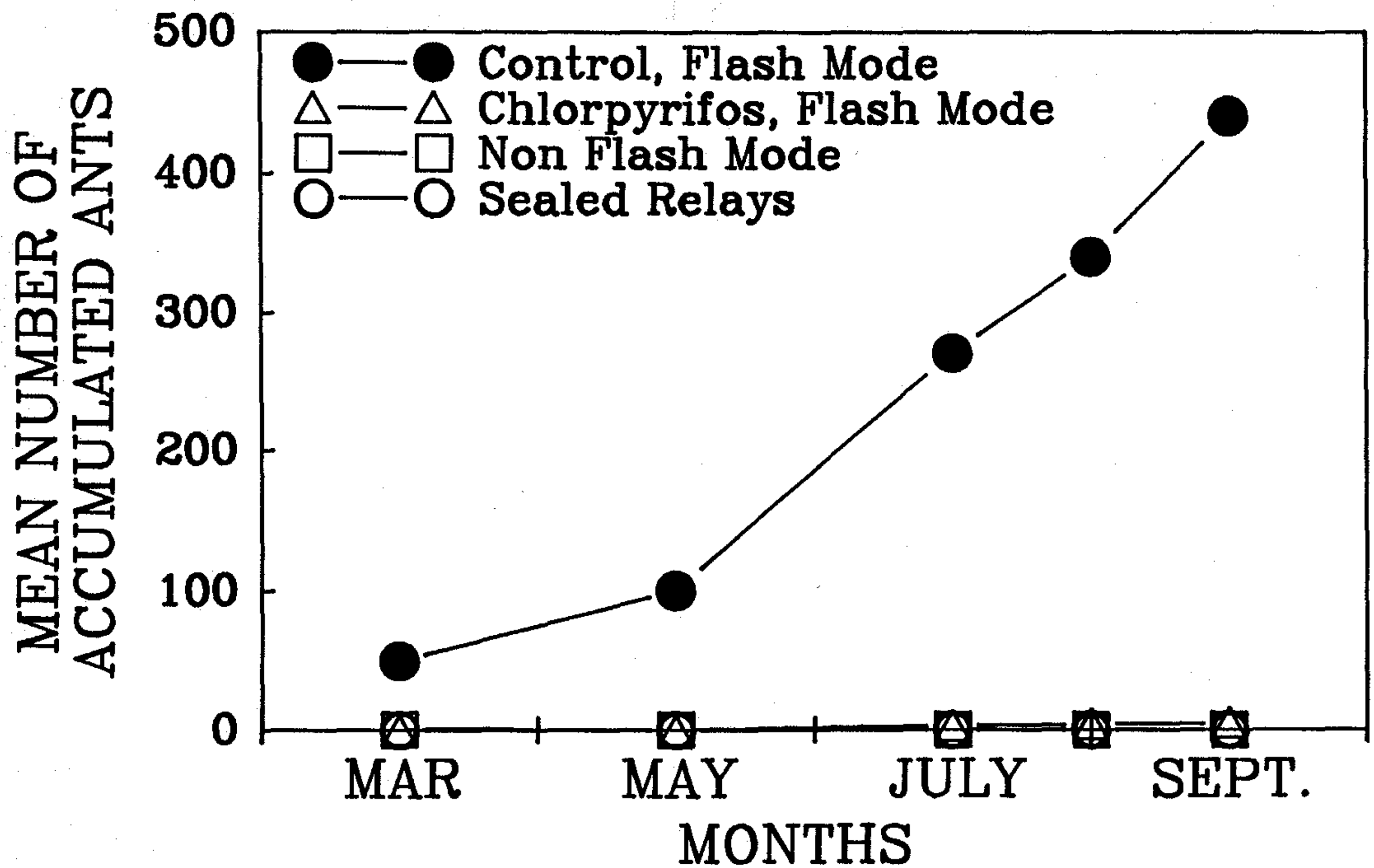


Figure 23. Accumulation of Fire Ants Inside Sealed and Unsealed Relay Switches.

V. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and treatment recommendations are provided from this research study of the imported fire ant and its infestation of traffic signals. These results are a synthesis of the initial field survey, the subsequent laboratory experiments, the signal cabinet experiments conducted in nearby cities for two years, and the research team's collective judgments.

1. GENERAL CONCLUSIONS

The imported fire ant has rapidly spread across the southern United States since the 1940's. Recent evidence indicates that they will become a more serious problem in Texas due to the expansion of multiple-queen colonies. These colonies occur at much higher densities than did the original single-queen colonies.

Fire ants have a typical annual activity cycle in Texas that is strongly influenced by ambient temperature and precipitation. Fire ants become dormant when the temperature falls below 45ºF. Activity increases with increasing temperature until very hot and/or extremely dry summer conditions are reached. The annual activity cycle of fire ants in Texas begins in late winter or early spring as the temperature rises.

New colonies are formed beginning in late April when thousands of virgin queens and mates leave each mound and begin their mating flights. These flights usually begin around 10:00 a.m. one or two days following a rain, if that day is warm (above 75ºF), not too windy and generally sunny. Mated females fly toward reflective or moist areas on which to land. Curbsides make attractive landing sites and nesting areas. Queens begin laying eggs within 24 hours. If there is sufficient time during the season to build a colony, it will probably survive.

Fire ant activity remains high during the spring and early summer as thousands of foragers search for food. Other ants tend the queens, larvae, eggs and provide other services to the colony. It is during the summer season that fire ants become a serious problem in signal cabinets.

Traffic signal cabinets are believed to be attractive to fire ants for several reasons:

1. They are usually located next to street and road curbsides, which are attractive to queens for nest building.

2. They provide protection from cold weather and the elements. In addition, surrounding landscape may be treated with insecticide which may push ants into the cabinets.
3. The cabinets are connected to buried electrical conduits which provide a pathway for the ants.
4. They contain many sources of electrical fields. Our research has shown, corroborated by other significant empirical evidence, that fire ants (and other species of ants) are strongly attracted to electrical fields. The larger the field magnitude, the stronger the attraction.
5. Electromechanical relays are a prime target of fire ants due to the intense electrical field strength at their contact points. Generated ozone is not an attractor.

Signal technicians want an extraordinarily powerful insecticide that kills all fire ants in cabinets, and keeps them out without any need to return for treatment again. Several insecticides were tested in signal cabinets. Of those tested, insecticides containing chlorpyrifos appear to be the most effective in traffic signal cabinets. We recommend that heptachlor-based products should not be used in traffic signal cabinets. We believe that heptachlor is too toxic to be used safely in signal cabinets, which are exposed to the elements and the public, and which must be serviced regularly. At the present time, heptachlor is only produced by one company in the United States (Rainbow Manufacturing Corporation, [4]). Chlorpyrifos is not as toxic to humans as heptachlor and has a shorter effective life span. It is EPA approved for treatment of surface installed electrical equipment. The chlorpyrifos product tested in this study contains 0.5% chlorpyrifos and is conveniently packaged in small bags (3 oz.) to safely expedite the treatment program in the field (provided by Rainbow Manufacturing Corporation).

An insecticidal treatment program using the chlorpyrifos-based insecticide was developed and implemented in both cities of Bryan and College Station, Texas. This treatment resulted in the destruction of all ants in treated cabinets within three hours. The effectiveness of this treatment lasted an entire year.

The treatment of cabinets with chlorpyrifos effectively reduced the number of ants that entered the relays, but sealing the relays with epoxy totally eliminated any accumulation of ants inside relay switches.

It is also important to take advantage of natural forms of control of fire ants. Spiders are a biological control of the fire ant in electrical equipment. Some species, such as *Steatoda triangulosa*, are specialist predators on the fire ant.

2. LABORATORY CONCLUSIONS

Laboratory experiments convincingly and repeatedly demonstrated that imported fire ants are strongly attracted to electric fields. Attraction is proportional to voltage level; the higher the voltage, the stronger the attraction. Fire ants were observed to quickly move to and accumulate on electrically charged points. Fire ants also showed some possible habituation, as they were not as strongly attracted when the experiment was replicated on the same day.

Experiments with other factors such as magnetic fields and ozone indicated no observable effect on the red imported fire ants. Thus, it appears that the electric field generated in electric circuits is the primary reason ants are attracted to electrical equipment.

Shorted circuitry is one of the major problems caused by fire ants in electrical equipment. Fire ants will remove insulation from wires in signal cabinets, allowing a short to occur. Both in laboratory and field experiments, it was established that there was no component in the insulation of various types of wire which attracted ants. Although not demonstrated in the laboratory, it appears that ants only attack wire when it is carrying electrical current.

Another major problem caused by the imported fire ant is the interference with the normal operation of electromechanical relay switches. This was observed in most cases when ants invade traffic signal control cabinets. The ants are highly attracted to active relay switches inside the cabinets because of the electric field generated between the contact points. They can accumulate inside the relays so tightly that the switch will no longer operate.

3. RECOMMENDED TREATMENT PROGRAM

Traffic signal technicians must be prepared to annually battle the potential invasion of fire ants into traffic signal cabinets in much of Texas. Consequently, the following annual treatment program is recommended:

1. Obtain the desired treatment products and supplies, such as:
   a. Cans of wasp and hornet spray for quick kill of insects in the cabinets.
   b. Plastic bottles of insecticide 1,1,1 trichloroethane for quick kill situations of fire ants in cabinets and around cabinet pads.
   c. An approved chlorpyrifos-based granular insecticide for treating fire ant infestation in signal cabinets. It is recommended to use a conveniently packaged product (0.5% in 3-ounce packages). Currently Rainbow Manufacturing Corporation may be the only supplier of such packages, which are also specifically labeled to control insects in electrical equipment [4]. Four 3-ounce packages are to be used in the smaller cabinets (floor area up to 4 sq. ft.); 8 packages in the larger cabinets (floor area up to 8 sq. ft.). Packages containing 24 ounces would be even more convenient for treating a cabinet with a base area up to 8 sq. ft. One-half of the package could be used for smaller cabinets (base area of up to 4 sq. ft.). It would require at least one year for such packages to be produced and approved by the EPA [4]. A number of companies market 0.5% chlorpyrifos products (Table 2). These products have an indefinite shelf life as long as the package is not opened [4]. Once a package is opened, the contents should be used within a few days. If the package is folded shut and wrapped with a rubber band or taped shut, the insecticide will be effective for at least six months [4].
   d. Vacuum and use environmentally safe disposal bags for used insecticide. The used insecticide can be packaged in strong plastic bags and legally disposed of with other buried waste [4]. It should never be left on the soil surface, as it can poison birds and other wildlife.
   e. Liquid insecticides based on chlorpyrifos or diazinon can be used to form a chemical barrier around signal cabinets.
   f. Wear appropriate protective clothing, including rubber gloves, when treating cabinets with insecticides.
2. Inspect all signal cabinets within assigned territory for fire ant infestation during the spring when the ants have become active in the local area. Typically, ant activity is high on a warm spring day following a major rain (1 inch in 24 hours). These conditions will usually occur in Texas during April or May.

3. Check for fire ant activity and nests around exterior of cabinet and look for ant trails leading into the cabinet. Eliminate the possibility that killer bees are in the cabinet. If killer bees are suspected to be in the cabinet, call an entomologist and do not open or disturb the cabinet.
4. Open a safe cabinet and visually inspect the interior of the cabinet for fire ants and their nests. Check for the presence of ants in electromechanical relays. Examine insulation on electrical cables to determine the extent, if any, of fire ants chewing on wiring.
5. Check previous year's maintenance records and insecticide treatment records for the installation. Rank the fire ant infestation situation for each cabinet as being one of the following cases:
   a. No problem - No fire ants visible inside or outside of cabinet. None for last year. No insecticide treatment performed last year.
   b. Small problem - A few fire ants observed foraging within or on the cabinet, but no nest or damage. No insecticide treatment last year.
   c. Infestation problem - All other cases. Many fire ants are seen in cabinet, dead ant piles observed, nests observed, chewed wires observed, ants observed in relays.
6. Vacuum and clean the cabinet. Save and carefully dispose of old insecticide removed from the cabinet in an environmentally safe and approved way, as described above (para. 1.d, page 47).
7. Where fire ants have entered electromechanical relays, remove the ants, and then seal the relays with an appropriate quick-setting epoxy. In future purchases, specify fire ant proof relay designs where possible.
8. Select the appropriate insecticidal treatment program for the cabinet, based on the level of problem observed:
   a. No problem - There is no apparent need to treat the cabinet.
   b. Small problem - A few ants around is normal nowadays in infested areas of the state, but this usually does not cause a big problem with annual maintenance. Since the cabinet is now clean, you should either spray or broadcast a chemical barrier of chlorpyrifos or diazinon insecticide around the inside base of the cabinet, or completely treat the inside of the cabinet with an appropriate commercial, chlorpyrifos-based granular insecticide. See below for a description of the latter treatment inside the cabinet.

c. Infestation problem - To the now clean cabinet, cautiously apply a chlorpyrifos-based granular insecticide evenly over the floor of the cabinet according to the manufacturer's recommendations. Note that the dosage level (and depth of coverage) is related to the floor size (area) of the cabinet. Never apply the granular insecticide in a cabinet where it will become wet. Dampness encourages the growth of mold (which reduces or eliminates the effectiveness of the product), and free water around the area where the insecticide is applied may contaminate the environment. Therefore, the base of the cabinet, including any holes in the concrete pad and PVC conduits, should be sealed to keep water out and to minimize the accessibility of the cabinet to fire ants. Once the cabinet has been sealed, apply the insecticide.

9. Appropriately record the insecticide treatment for the cabinet, including insecticide, dosage level, date and initial conditions observed upon inspection of the cabinet. Apply stickers (supplied by the insecticide company) both inside and outside the cabinet (near door handle) to warn others that the cabinet was treated with a toxic material. The stickers should indicate the insecticide used, the date it was applied, and a toll-free number (printed on the sticker supplied by the insecticide company) which can be used to obtain more information on the product.
10. All signal maintenance personnel must be informed that they are working with a toxic material and to take all necessary safety precautions to protect themselves when applying insecticides.
11. Holes in the concrete pad for the passage of cables should be sealed with concrete. A newly constructed cabinet should have a solid pad. Fire ants will construct nests in any hole in the pads. The open ends of the conduits should be sealed as well as possible, as they allow access of the ants into the cabinet.
12. The base of the cabinet should be sealed as well as possible with a silicon sealer. This may reduce the invasion of ants into the cabinet and would reduce the amount of moisture entering the cabinet.

This recommended treatment program should be monitored by SDHPT for rate of implementation, effectiveness, and for suggested revisions by field personnel and empirical evidence.

VI. FUTURE RESEARCH

Our research has generated a number of relevant questions, which should be answered in a timely manner:

1. What are the best methods for controlling ants in pull-boxes and conduits?
2. Why do ants remove insulation from wires? Does it only happen when the wire is carrying a current? What factors attract ants to the wires?
3. Why are ants attracted to electricity? How can circuitry be modified to reduce the attractiveness?
4. Can an electric trap be developed which would automatically remove the ants from a cabinet or other electrical equipment?

REFERENCES

[1] Little, E., "Ants in Electric Switches: a note," New Zealand Entomology, Vol. 8, p. 47, 1984.

[2] Gay, F. J., and J. H. Calaby, "Termites of the Australian Region," Biology of Termites, Vol. 2, pp. 393-448, 1970.

[3] Messer C. J., S. B. Vinson and G. A. Brouwer, "A Survey of Fire Ant Infestation in Traffic Signal Systems," Research Report 1135-1, Texas Transportation Institute, 1986.

[4] Barbara Cheazes, Rainbow Manufacturing Corporation, Personal Communication. April, 1989.