A LABORATORY EVALUATION OF CRACK AND CREVICE TREATMENTS FOR CONTROL OF THE GERMAN COCKROACH, BLATELLA GERMANICA (LINNEAUS), USING VARIOUS NOZZLE TYPES, NOZZLE HEIGHTS, AND CRACK WIDTHS

By

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CHAPTER I

INTRODUCTION

Two major concerns have emerged in the last decade -- conservation of the world's energy supply and environmental awareness. Due to an increased cost in production and an effort to conserve the world's oil supply the manufacturing costs of oil derivatives has risen. As a result, insecticide prices have increased, thus increasing the Pest Control Operator's (PCO) overhead expense and reducing his net income. To counterbalance this increase in expenses, PCOs must obtain the most efficient control with the least amount of chemical thereby reducing overhead costs and environmental contamination.

The federal government, realizing the importance of preserving the environment, established national agencies like the Environmental Protection Agency (EPA) to regulate all types of pollution including insecticide contamination. To reduce the danger of insecticide contamination EPA guidelines have been established for residual application of insecticides in private residences and commercial establishments. These treatment guidelines are as follows:

General - Broadcast application to surfaces (walls, floors, ceilings, or outside treatment) in non-food areas.

Spot - Noncontinuous application to limited areas (2 square feet) which insects occupy but which are not in contact with food, food utensils, or workers.

Crack and crevice - Application of small amounts of chemical directly into cracks and crevices where insects hide or enter.

The definition of crack and crevice refers to an opening resulting from expansion joints between different construction elements or the area between equipment bases and floors which may lead to void areas such as hollow walls, equipment legs and bases, conduits, motor housing, junctions, or switch boxes.[1]

The primary objective of this study was to determine the most efficient nozzle and nozzle height to control the German cockroach, Blatella germanica (L.), in crack and crevice treatment.

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[1]Dr. C. Douglas Mampe, Part 1 - Legal Aspects of Application, July Pest Control, 1976.

CHAPTER II

LITERATURE REVIEW

Early Insecticide Evaluation Techniques

Using a test apparatus to evaluate an insecticide's effectiveness was not a new concept. Between the 1920's and the 1930's many methods were devised. Tattersfield (1939) illustrated three means of applying insecticides to insects: (1) spraying pests - Peet-Grady Chamber (1928) and the Campbell Turntable Method (1939); (2) dropping - Standard Oil Drop Method (1934); and (3) dripping - Sheperd and Richardson (1931), modified by Crawford and Benson (1938).

All of these methods depended upon spraying (depositing) a known amount of insecticide at a defined pressure from a certain height on a selected number of insects. Since the insecticides evaluated were contact materials, emphasis was upon the placement of the chemical on the insects. Due to the direct placement or confinement of the insects to the insecticide, data collected varied from field conditions.

The major problem associated with early research was a lack of accuracy. Repeating experiments failed to substantiate previous results. Braderstcher (1936) showed that not only many different results could be obtained using the various methods, but different insecticides had relatively different levels of toxicity depending upon the method used. Not until 1938 when Crawford and Benson modified the Shepard and Richardson dipping method did accuracy improve. These modifications enabled the researchers to determine the amount of insecticide placed on the insects.

Development of New Application Equipment

The majority of the insecticides used during this period were contact insecticides which were applied in powder or dust form. As chemical technology advanced, the formulation of insecticides changed from dust to wettable powder and emulsifiable concentrates. Along with this change came new groups of insecticides which had residual activity. Various types of nozzles and equipment have been developed to distribute these new formulations.

Pelej (1956) studied various nozzles to determine which patterns provided the most desirable spray patterns for different spraying situations. He found that the fan nozzle could be used for most applications, while the pin stream worked well for inaccessible areas.

Potter (1941) revised Tattersfield's apparatus for evaluation of insecticides. Potter's method consisted of revising Tattersfield's atomizing nozzle and incorporating a spray tower which resulted in a more uniform spray deposit on a six inch plate. By utilizing this method, Potter was able to reduce the variation in total deposits from 10% to 20% in a series of applications.

Howlett (1946) improved the design of the atomizing nozzle by the addition of a reset screw which allowed the distance of the inner cone to the outer cone to be adjusted. This made it possible to repeat the nozzle setting after washing.

History of Spray Pattern Research

As insecticide formulation and equipment improved, investigators initiated comprehensive studies on spray deposits. Research conducted by Glasgow (1947) indicated that the smaller the droplet the greater the coverage compared to an equivalent amount of the same chemical dispersed as larger droplets.

Potter (1941) worked with atomizing nozzles that produced jet streams. He observed a heavier deposit in the center with the amount being deposited decreasing toward the outside of the sprayed area when spray is applied directly to the surface. When Potter fluctuated pressures, he found that increased pressure caused greater turbulence under given conditions. Follow-up studies by Potter (1946) showed that an increase in atomization resulted in an increase in concentration of insecticide which was necessary to obtain an adequate dosage rate due to less volume of insecticide needed to cover a given area.

Potter (1946) studied particle sizes of insecticides applied as dusts, oil-coated dusts, and concentrated sprays. He concluded that particle size greatly affected the amount of insecticide deposited. Droplets less than 30 microns in diameter were repelled from objects. Maximum amounts of insecticide were deposited when the droplet size ranged in size from 30 to 100 microns. In addition, he found that many other factors affected droplet size, such as environmental conditions, humidity, and temperature as well as insecticide concentration and type of equipment used.

Kerr and Rafferty (1946) work with a pressure valve designed for the Peet-Grady atomizer. They found that the factor determining the size and space distribution of droplets was the pressure operating the atomizer.

Yeoman and Rogers (1953) studied the relationship of droplet size and degree of deposit. They found that droplets 50 microns and less in diameter had a tendency to drift. They concluded that sprays with larger droplets would treat more surface area.

Rogers et al. (1973) evaluated four nozzle types: Spraying Systems 50015, 800067, Multi-Teejet® fan nozzles, 8002 Unijet® fan nozzles, and a jet stream nozzle. They concluded that by increasing tank pressure and decreasing operation speed the amount of drift and runoff was increased. They also found that spraying with a tank pressure of 20 psi and an application speed of 2.5 ft/sec was optimal for practical application with minimal drift and runoff under laboratory conditions.

Berry (1975) tested an apparatus that simulated typical crack and crevice situations. Using this apparatus, Berry was able to investigate spray deposits and drift under varying conditions. His findings indicated that crack width and depth had very little effect on the amount of spray deposited. Factors such as rate of application, concentration of insecticides, and tank pressure had a more direct effect on the degree or amount of spray deposited.

Insecticide Residual Studies

Lykken (1967) and Keil et al. (1969) studied the danger of pesticide usage around the home. These studies indicated that most people that use pesticide around the home failed to follow proper safety practices. In 1968 the United States Department of Agriculture suggested that all dishes and utensils be removed from an area being treated for insect pests (anonymous). These agencies were referring to insecticide residues deposited on the items if not removed during treatment.

Due to insufficient information on pesticide residues, Wright and Jackson (1971) initiated a study to determine the amount of insecticide deposited on dishes after treatment of kitchen cabinets. They used very accurate equipment and analyzed the amount of propoxur, chlordane, and diazinon deposited on the dishes. Their findings showed that insecticide residues were greatly reduced the day following treatment. Dishes on the top of the stack received the highest amount of insecticide.

Wright and Jackson (1975) initiated follow-up studies that investigated deposits of insecticide residues in non-target areas after crack and crevice treatment using aerosol and compressed-air sprayers. Results showed that aerosol sprays had less movement.

Bennett (1976) evaluated levels of diazinon residues in food after commercial establishments were treated using both spot and crack and crevice treatments. The residue levels in both the wrapped and unwrapped food was well below the allowable residue levels.

Shore (1974) used mathematic equations to estimate theoretical amounts of insecticides deposited in cracks and crevices following treatment. As a result of his study, Shore set forth three assumptions: 1) toxic materials last longer in cracks and crevices, 2) cockroaches pick up toxic materials at a faster rate in cracks and crevices, and 3) insecticides sprayed into cracks and crevices will build up a thicker film of residue than when applied to flat surfaces.

CHAPTER III

METHODS AND MATERIALS

Test Apparatus

Berry (1975) devised a test apparatus (Figure 1) which artifically simulated cracks and crevices found in houses (baseboards, shelves, and void areas around furniture). This was utilized to evaluate the effectiveness of various nozzles in controlling the German cockroach, Blatella germanica (L.). The test apparatus consisted of a base and two surface plates constructed of sheet aluminum. The base served as a foundation for the two surface plates. The surface plates were adjustable which allowed for the various crack widths that were used in the study. C clamps were used to secure the plates so that a constant crack width was maintained throughout the treatment.

Modification of Sprayer

The sprayer utilized was a modified B & G model number 104-S (Figure 2). The modifications consisted of replacing the standard pump assembly with a petcock, air regulator, outside air inlet, and an air pressure gauge allowing for an accurate and constant air pressure to be maintained throughout the test.

Another identical unit was installed to allow the use of additional nozzles simultaneously. A 17.6 kg/cm^2 portable air tank was the air

Figure 1. Test Apparatus Used Throughout Test to Simulate Cracks and Crevices

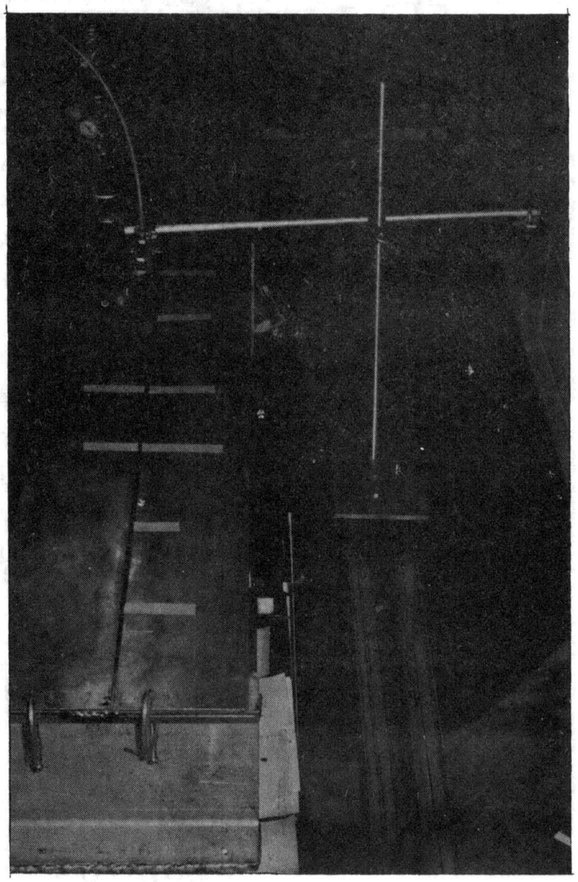
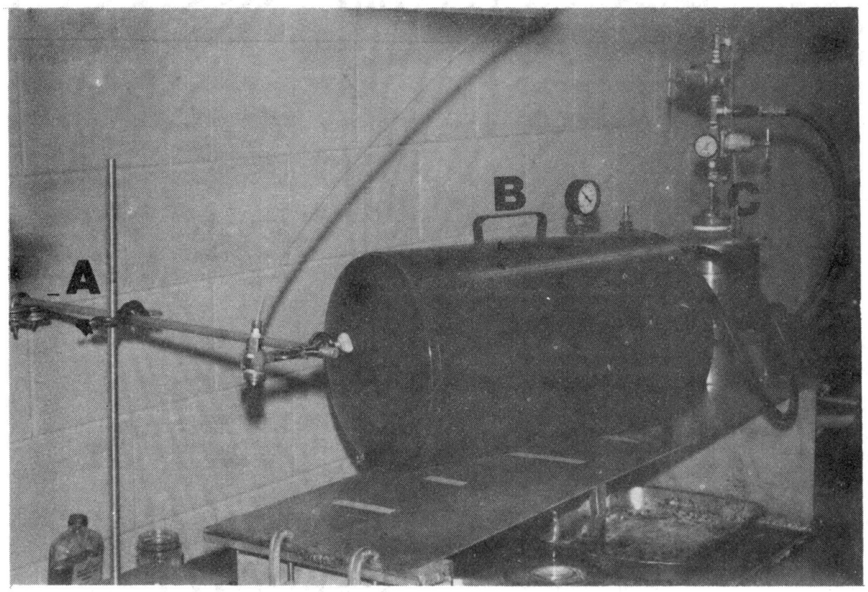


Figure 2. Application Equipment: A, Nozzle Assembly; B, Portable Air Tank; and C, Modified Spray Tank



A
B
C

source. Two materials were sprayed during the test DF-545 water soluble dye and Diazinon® 4E.

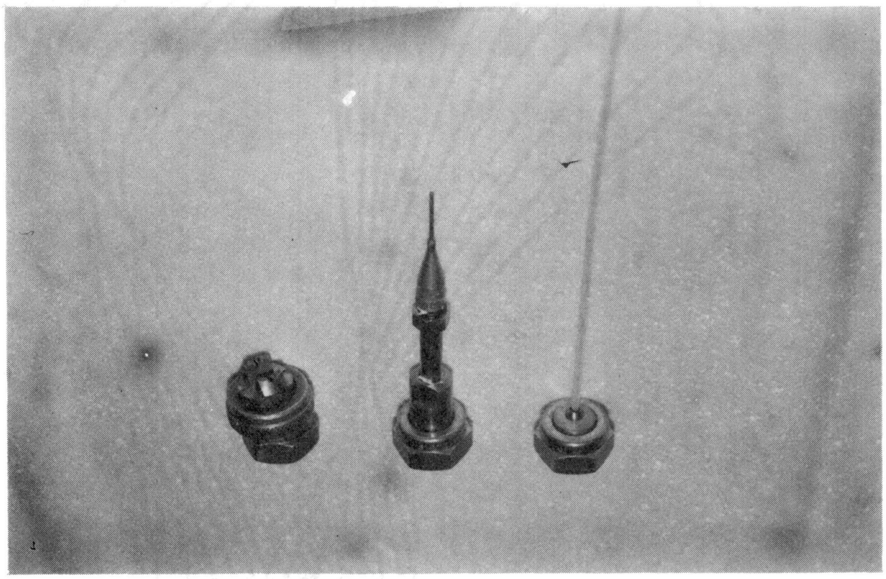
Type of Nozzle

The three nozzles (Figure 3) utilized during the test were (1) Spraying Systems Multi-Teejet® nozzle 800067, (2) Spraying Systems Crack and Crevice nozzle 14915, and (3) B & G 100 C.C. Crack and Crevice Tip Extension. The Multi-Teejet® nozzle 800067 was a fan spray while both crack and crevice nozzles were pin streams with a nozzle diameter of 0.128 mm. The differences between the two crack and crevice nozzles were the length of the extended tip and the type of material used in construction. The B & G nozzle consisted of a flexible plastic 15.36 cm extended tip while nozzle 14915 was a 1.58 cm extended tip constructed of brass.

Calibration and Conversion Methods

Rogers (1973) found that operator speed was extremely important in controlling the amount of drift and spray applied. He found that an application speed of 2.5 ft per second (.75 m per second) was the most economical and effective when using the Multi-Teejet® nozzle setting 800067 and 50015 at 20 psi (1.38 kg/cm²). For this study, calibration was converted into metric measurement and used as the standard to calibrate all speeds used with the various nozzles (Table 1). This made it possible to apply equal amounts of chemical when using a constant pressure. The technique used for spraying involved the use of a nozzle stand and a motorized track that maintained a constant nozzle height and tank pressure.

Figure 3. Nozzles Utilized: Spraying Systems Multi-Teejet® Nozzle 800067, Spraying System Crack and Crevice Nozzle 14915, and a B & G Crack and Crevice Nozzle



Spraying Techniques

Spraying techniques employed consisted of a nozzle stand and a motorized track which helped maintain constant nozzle heights at fixed application speeds. The nozzle stand (Figure 4) consisted of a cart and two bars -- one vertical bar permanently attached to the cart and a horizontal bar which was detachable. Two clamp holders were employed to secure the horizontal bar to the vertical bar and a clamp holder was used to attach the nozzle to the horizontal bar. By utilizing these clamps, it was possible to adjust the angle and height of the nozzles above the crack (test apparatus). To insure constant application rates, a motorized track device was designed by the Oklahoma State University Agricultural Engineering Department. The track chain was powered by an electrical motor (Zero max® 0-400). The nozzle stand was pulled by attaching it to the chain. The speed was adjustable and indicated by a calibrated speedometer. Due to the application rates being in meters per second, speeds were determined by marking the chain and measuring the time required to travel a distance of 1.53 meters.

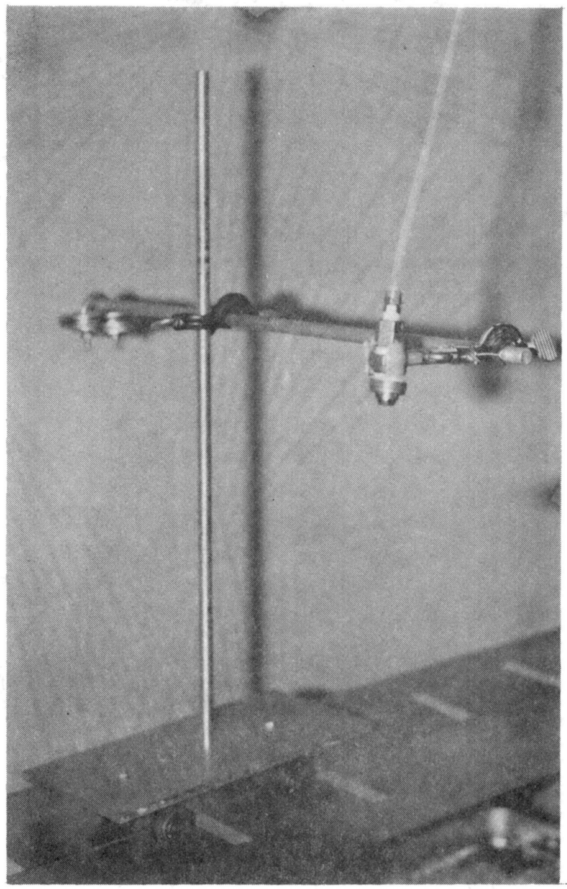
Pre-Test Procedures

Washing Technique Evaluation

Prior to starting actual data collection for this study, a test was initiated to determine if any diazinon residues remained in the test jars after washing. A battery jar was placed beneath the simulated crack and crevice and sprayed with a 1% solution of Diazinon® 4E and allowed to dry for a twenty-four hour period.[1] After treatment the

[1]Solution strength recommended in the 1975 Pest Control Association Technical release, Good Practices in German Cockroach Control.

Figure 4. Nozzle Stand Assembly

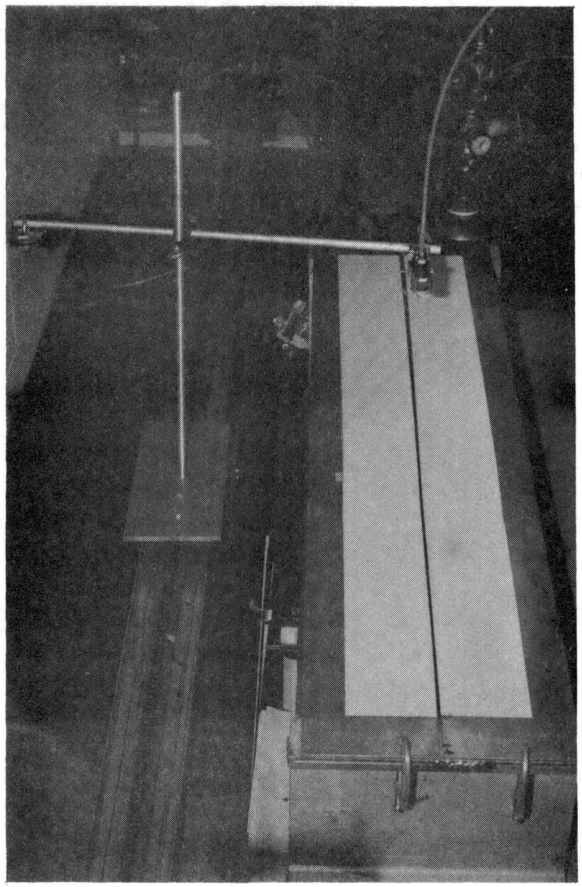


test jar was washed with a 1% solution of Liqui-Nox detergent® (manufactured by Alconox Inc.). After washing, five adult cockroaches were released in the test jar for an additional twenty-four hour period. The washing procedure was shown to be adequate, as no mortality occurred. For the purpose of this test, death was defined as 'no coordinated movement' after cockroaches had been probed with a sharp object. As an additional check on the procedure, five more cockroaches were released in the test jar for a twenty-four hour period one week after washing. No cockroach mortality was observed. This washing procedure was used throughout the duration of the test.

Evaluation of Spray Patterns to Determine Tank Pressure and Nozzle Heights

Spray patterns from the various nozzles were evaluated to determine how tank pressure affected the amount of spray deposited and the degree of coverage. Three strips of poster board measuring 122.8 cm x 10.26 cm were positioned on either side and below the crack (Figure 5). The crack with the poster board strips in place was sprayed with four grams of fluorescent dye in one gallon of water. At this rate, the crack and crevice nozzles occasionally clogged. The clogging was attributed to the small diameter (0.128 cm) of the nozzle orifice. Clogging was eliminated by reducing the dosage rate to two two grams of dye per gallon. After a thirty-minute drying period, the spray patterns were examined with the aid of a black light. Spray patterns were photographed using a Wratten Kodak 2b filter on the camera lens. The procedure was the same method used by Rogers (1973). The test involved evaluating the following variables: (1) two crack widths

Figure 5. Position of Posterboard Strips on Either Side and Below the Crack's Opening



(2 mm and 5 mm), (2) three nozzle types (Spraying Systems Multi-Teejet® nozzle 800067, Spraying Systems Crack and Crevice nozzle 14915, and a B & G 100 C.C. Crack and Crevice tip extension), (3) four nozzle heights (4 mm inside the crack and 5 mm, 75 mm, and 150 mm above the crack) and (4) two tank pressures (1.05 kg/cm² and 2.1 kg/cm²). The test was conducted at various application speeds.

To determine if the pin stream's separation into droplets affects the performance of the crack and crevice nozzles, a test was initiated to determine pin stream length before droplet formulation. To aid in the evaluation, a strobe light and 150 mm ruler were utilized. The sprayed solution was water at a tank pressure of 1.05 kg/cm². Before measuring, the spraying system was activated allowing for the tank pressure to be set and to flush the air bubbles out of the spray hose assuring a uniform pattern. After flushing, the strobe light was turned on to allow for the pin stream separation to be seen. Then the distance from the nozzle tip to the point of droplet separation was measured.

German Cockroach Mortality Test

The analysis of the test was done by the Oklahoma State University Statistics Department. The statistical method utilized was a completely randomized design with three replications. A replication was a complete randomization of 16 treatment combinations, simultaneous analysis over a twenty-one day period after spraying. Analysis of variance tables containing mean squares and probability of higher F values for various treatment combinations are included in the appendix.

The motorized track and artificial crack (test apparatus) were positioned so that the nozzle assembly could travel the length of the crack directly over the crack opening. The motorized track was approximately 3.68 meters long. This length allowed the nozzle assembly to travel a distance of .92 meters before and after spraying the target area. This extra distance insured that the nozzle assembly would reach the calibrated speed before spraying the target area.

Before the spraying system was activated, the crack's width and nozzle height were accurately determined. A trial run was initiated to align the nozzle and to eliminate air bubbles in the spray hose insuring a uniform spray pattern.

Battery jars were used to simulate the interior of the crack and crevice. These jars measured 15.36 cm x 20.48 cm and were inserted beneath the crack at the designated target area. The target area measured 15.36 cm long and was marked on the surface plates to aid in determining the degree of coverage and to insure constant placement of the battery jars (Figure 6). After jar placement, the spray was activated passing over the target area once. After spraying, the spray deposits were allowed to dry for a thirty-minute period. Degree of coverage was based on visual observation of the sprayed surface with the aid of a black light which rated the spray coverage as complete (Figure 7), broken (Figure 8), or completely missed (Figure 9). Due to shortage of space, the battery jars were removed and placed on shelves.

After each treatment, the crack width and nozzle height were reset and the nozzle realigned. To insure maximum nozzle flow, the nozzle's screen was cleaned between each spray treatment.

Each replication consisted of releasing ten adult cockroaches into

Figure 6. Position of the Battery Jar Below the Designated Target Area

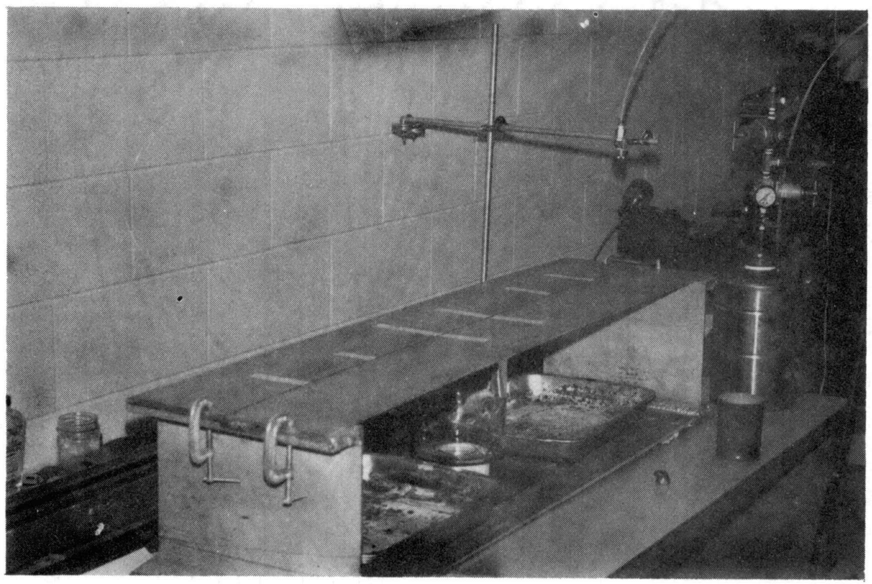


Figure 7. Complete Degree of Spray Coverage Inside the Crack

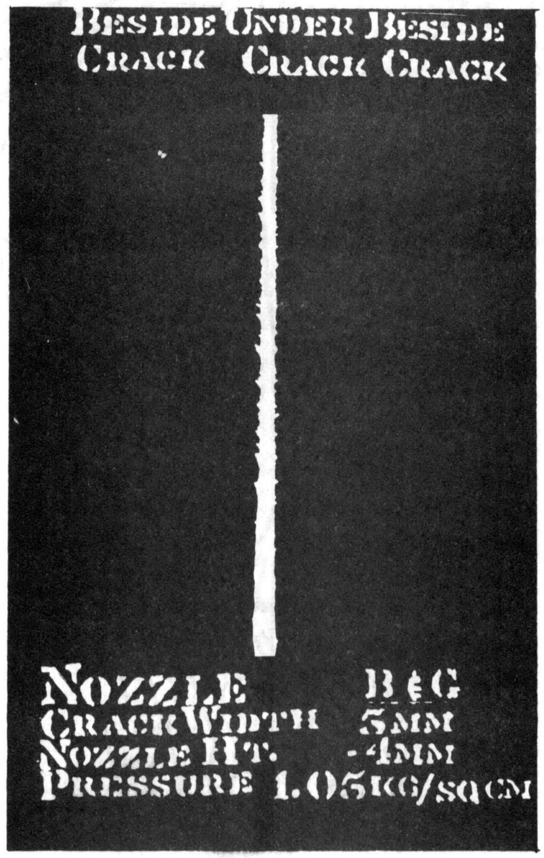

BESIDE CRACK
UNDER CRACK
BESIDE CRACK
NOZZLE B&G
CRACK WIDTH .5MM
NOZZLE HT. -4MM
PRESSURE 1.05KG/SQ CM

Figure 8. Broken Degree of Spray Coverage Inside the Crack

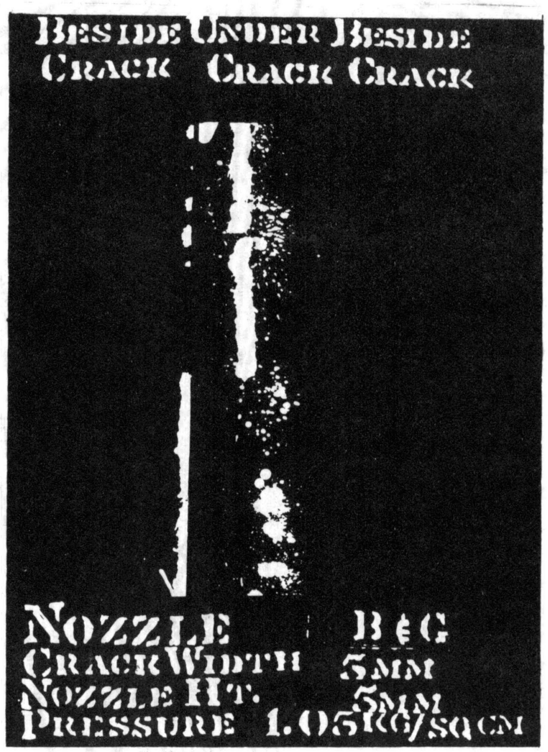
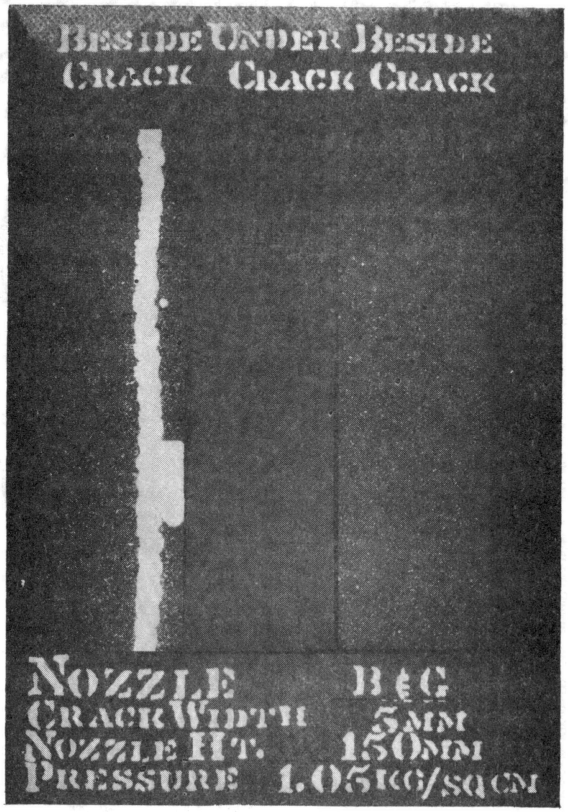

BESIDE CRACK
UNDER CRACK
BESIDE CRACK
NOZZLE B&G
CRACK WIDTH 5MM
NOZZLE HT. 5MM
PRESSURE 1.05 KG/SQ CM

Figure 9. Completely Missed Degree of Spray Coverage Inside the Crack


BESIDE UNDER BESIDE
CRACK CRACK CRACK
NOZZLE B & G
CRACK WIDTH 5MM
NOZZLE HT. 150MM
PRESSURE 1.05KG/SQ CM

the sprayed battery jars at intervals of 1, 7, 14, and 21 days. The cockroaches remained in the jars for thirty minutes. After the thirty-minute period, the cockroaches were transferred to one-half gallon cardboard ice cream containers. A vaseline and mineral oil solution was sprayed along the edge of the holding containers to prevent the cockroaches from escaping. After a twenty-four hour period, cockroach mortality was calculated. The mortality in the treated containers was compared to the mortality in the untreated containers. This method is similar to the method described by Ebeling et al. (1967) and Rogers et al. (1970).

The check consisted of four ice cream containers containing ten cockroaches each. These cockroaches were handled in the same manner as the other cockroaches except they were not exposed to the treated battery jars. Handling consisted of transferring the cockroaches from their living quarters to individual ice cream containers. This was accomplished by submerging a five-gallon aquarium in an ice chest filled with ice. After thirty minutes, cockroaches were released into the submerged aquarium until sluggish behavior was observed. Then with the aid of a forcep, ten cockroaches were placed in each container and transferred to the laboratory.

CHAPTER IV

RESULTS AND DISCUSSION

Pre-Test Activities

Spray Pattern Evaluation

Spray patterns resulting from various treatment combinations were evaluated with the aid of a fluorescent dye and a black light to determine if tank pressure affected the amount of spray deposited inside the crack. Examination of the spray patterns revealed that increased tank pressure did not increase the degree of coverage. However, increased pressure did increase the spray band width with nozzle 800067 (Figures 10 and 11). This width increase resulted in a greater degree of contamination outside the crack with the same amount of spray being deposited inside the crack. The additional pressure caused splashing (Figures 12 and 13) which increased the chance of contamination to non-target areas. The spray pattern of the crack and crevice nozzles inside the crack remained relatively uniform at both tank pressures (Figures 14 and 15). The lower tank pressure (1.05 kg/cm²) gave the same degree of coverage with the least amount of contamination and spray waste.

Rogers et al. (1975) stated that the minimum pressure required to deliver a uniform spray from a fan nozzle was 1.05 kg/cm². This was the maximum pressure recommended to be used with the Spraying Systems

Figure 10. Spray Pattern for Nozzle 800067 at a Height of 150 mm and a Crack Width of 2 mm Using a Tank Pressure of 1.05 kg/cm^2

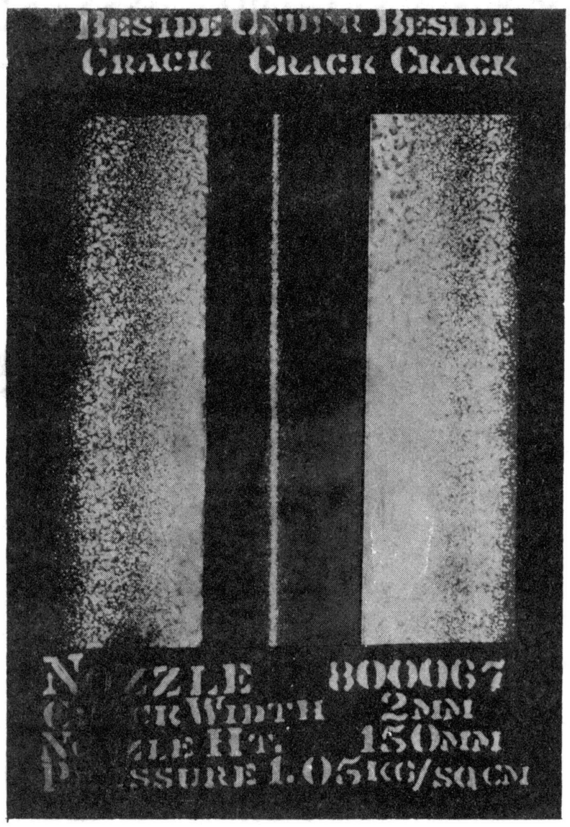

BESIDE BESIDE
CRACK CRACK CRACK
800067
2MM
150MM
1.05KG/SQCM

Figure 11. Spray Pattern of Nozzle 80067 at a Height of 150 mm and a Crack Width of 2 mm Using a Tank Pressure of 2.1 kg/cm^2

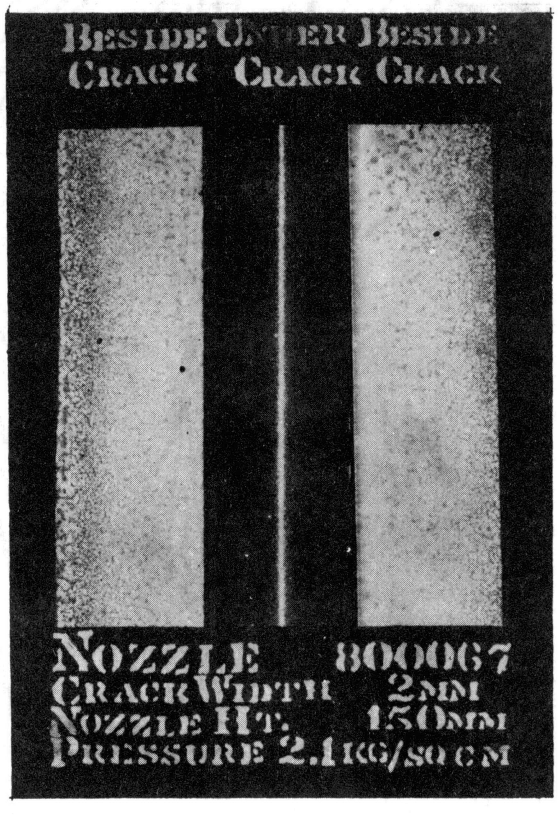

BESIDE UNDER BESIDE
CRACK CRACK CRACK
NOZZLE 800067
CRACK WIDTH 2MM
NOZZLE HT. 150MM
PRESSURE 2.1KG/SQ CM

Figure 12. Spray Pattern for Nozzle 800067 at a Height of 5 mm and a Crack Width of 5 mm Using a Tank Pressure of 1.05 kg/cm^2

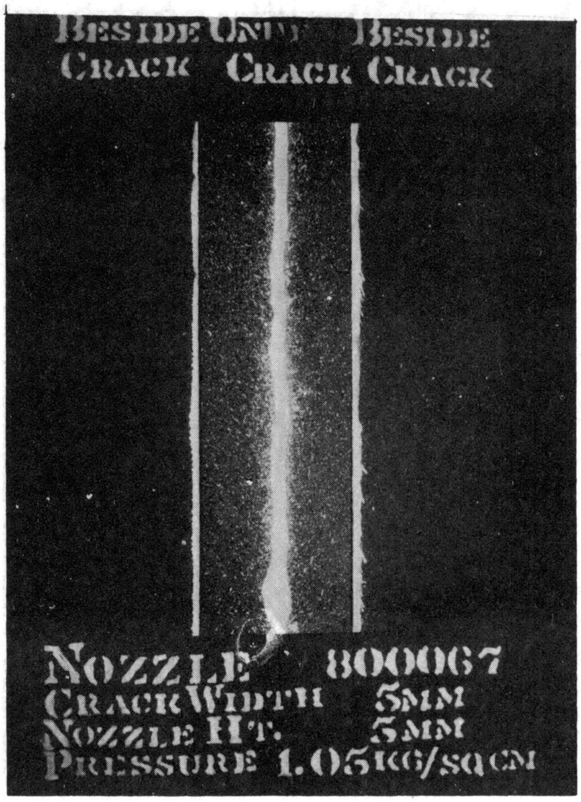

BESIDE CRACK
ONTO CRACK
BESIDE CRACK
NOZZLE 800067
CRACK WIDTH 5MM
NOZZLE HT. 5MM
PRESSURE 1.05KG/SQCM

Figure 13. Spray Pattern of Nozzle 800067 at a Height of 5 mm and a Crack Width of 5 mm Using a Tank Pressure of 2.1 kg/cm^2

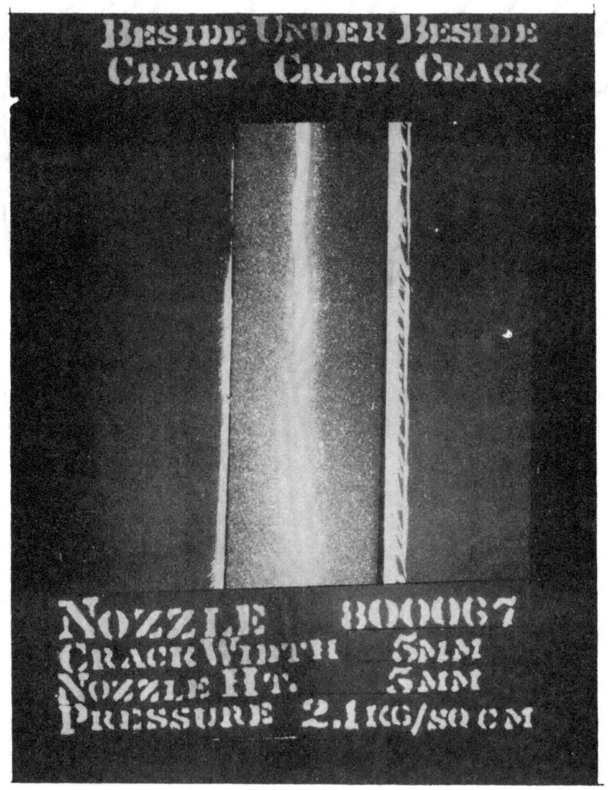

BESIDE UNDER BESIDE
CRACK CRACK CRACK
NOZZLE 800067
CRACK WIDTH 5MM
NOZZLE HT. 5MM
PRESSURE 2.1 KG/SQ CM

Figure 14. Spray Pattern of a B & G Nozzle at a Height of - 4 mm Inside the Crack and a Crack Width of 5 mm Using a Tank Pressure of 1.05 kg/cm^2

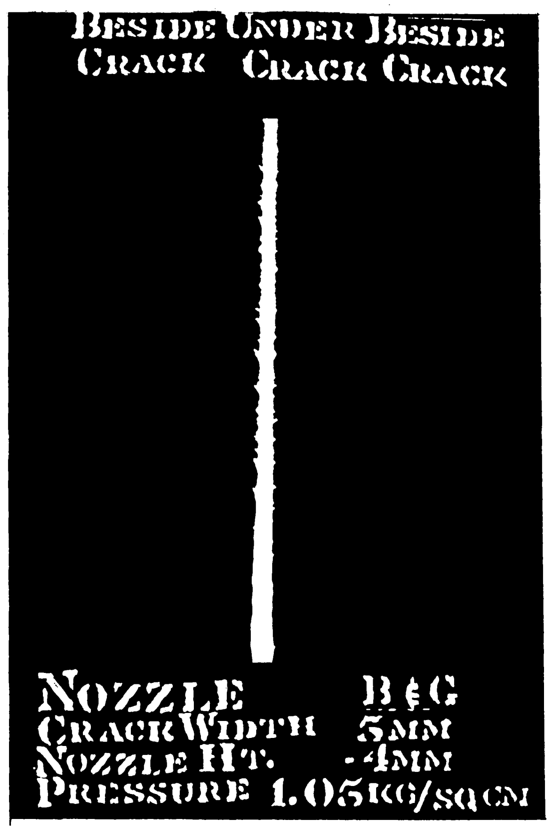
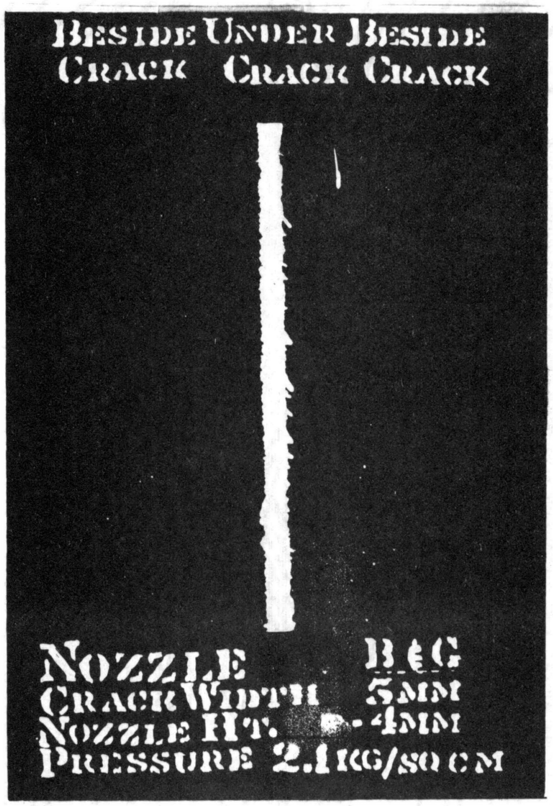

BESIDE UNDER BESIDE
CRACK CRACK CRACK
NOZZLE B & G
CRACK WIDTH 5MM
NOZZLE HT. -4MM
PRESSURE 1.05KG/SQCM

Figure 15. Spray Pattern of the B & G Nozzle at a Height of - 4 mm Inside the Crack and a Crack Width of 5 mm Using a Tank Pressure of 2.1 kg/cm²


BESIDE UNDER BESIDE
CRACK CRACK CRACK
NOZZLE B&G
CRACK WIDTH 5MM
NOZZLE HT. 4MM
PRESSURE 2.1 KG/SQ CM

Crack and Crevice nozzle 14915. This tank pressure was utilized during the cockroach mortality tests because there was no added advantages in the amount of spray deposited or degree of coverage at a higher tank pressure.

Determining Nozzle Heights to be Used to Treat Cracks and Crevices

Nozzle heights were determined after measuring the distance before the pin stream separated into droplets. Each nozzle pin stream was measured using a strobe light and a 150 mm ruler. Both crack and crevice nozzles had different separation points. Spraying System nozzle 14915 formed droplets 15 mm from the tip, and the B & G 100 C.C. Crack and Crevice tip extension formed droplets 30 mm from the nozzle tip.

By knowing the distances before the pin streams separated - 15 mm and 30 mm - the nozzle height could be determined. One height below 15 mm before the pin stream separated and the other height above 30 mm after the pin stream separated into individual droplets. The height chosen below the crack was 4 mm. Comparisons could be made with the crack and crevice nozzles at this height. The other heights were 5 mm and 150 mm above the crack. This enabled the fan nozzle to be compared to the crack and crevice nozzles.

Cockroach Mortality Varying Nozzle Type, Nozzle Height, and Crack Width

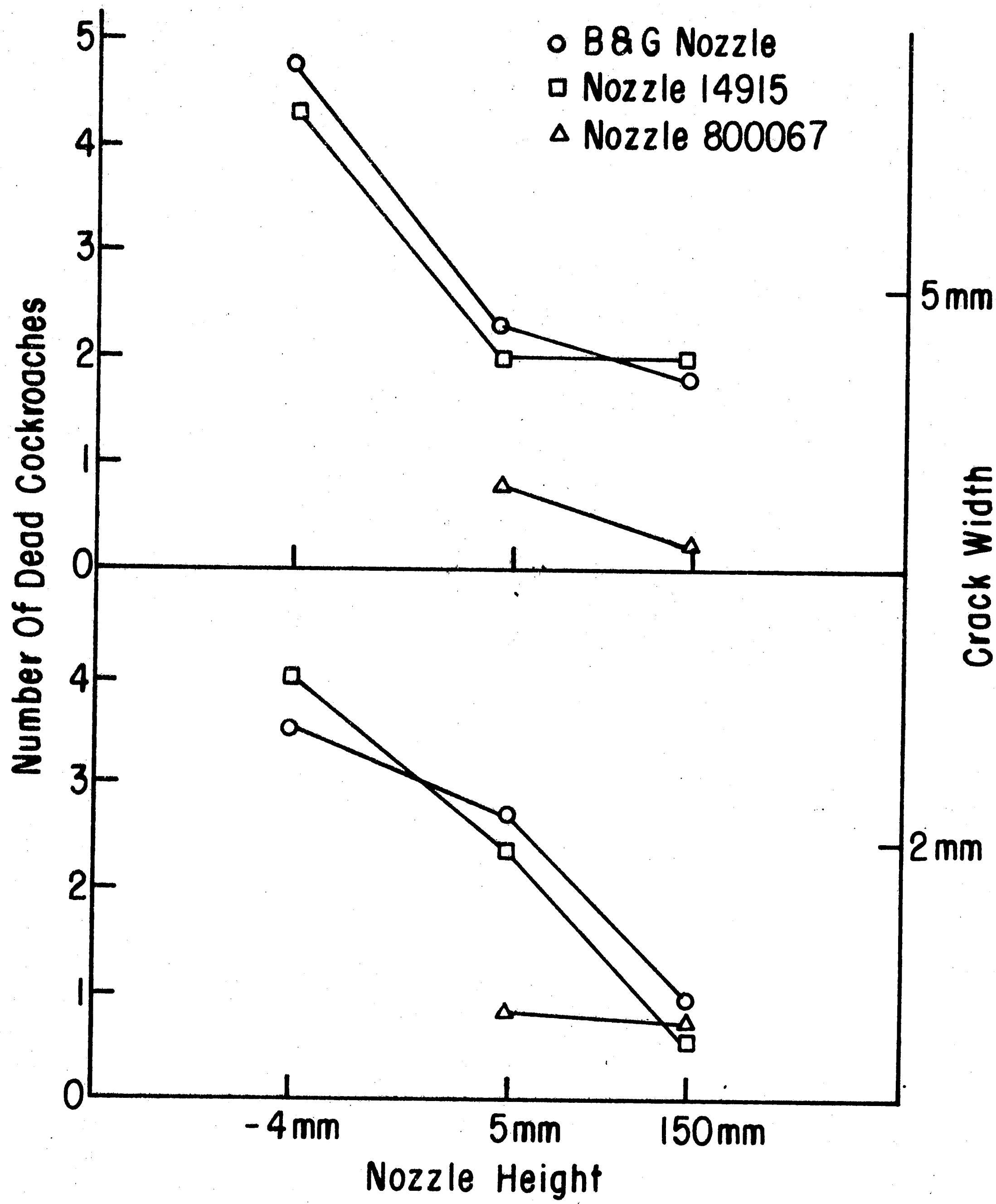
Cockroach control was based on the amount of chemical deposited and the degree of spray coverage inside the crack. Varying the nozzle type, the nozzle height, and the crack width affected the amount of chemical deposited and the degree of spray coverage cockroach mortality. To determine if there was any significant difference in the nozzle type, the nozzle height, and the crack width, two separate A.O.V.'s were utilized. One compared three nozzles at two nozzle heights and two crack widths (Table 2) and the other analyzed only the crack and crevice nozzles at two nozzle heights and two crack widths (Table 3).

Analysis of variances of the data comparing the three nozzles indicated significant differences in nozzles. This was illustrated in the mortality average for each nozzle (Table 4). Both types of crack and crevice nozzles had higher mortality averages associated with them than nozzle 800067. The only exception, nozzle 14915's mortality average at a crack width of 2 mm at a height of 150 mm. The possibilities for lower than expected mortality was attributed to a poor degree of spray coverage which resulted in poor control. The cockroaches tended to climb upward away from the treated surface when they were released into the battery jar. Large untreated surface beneath the crack resulted, due to the size of the battery jars allowed the cockroaches to aggregate away from the sprayed surface. The possibility also existed that the insecticide repelled the cockroaches from the treated area or area of deposits. Sterling and Howell (1972) findings showed that additives used in pesticides formulation could exhibit a certain amount of repellency to cockroaches for at least three weeks after being applied.

The average cockroach's total mortality over a twenty-one day period using the nozzles at two crack widths and three nozzle heights are presented in Table 5. Comparing average mortality at each nozzle height, there was no significant difference in cockroach mortality at the two crack widths. To summarize Table 5 a higher mortality generally resulted at the larger crack widths. The only exception was at the nozzle height of 5 mm where the smaller crack width had a slightly greater kill. Crack width became a factor when the nozzle was above the crack. As crack width increased, there was a greater chance for the spray to be deposited inside the crack due to the increase in the target area.

A graphic illustration of the three nozzles' total average cockroach mortality over a twenty-one day period at two crack widths and three nozzle heights is presented in Figure 16. Treatment combinations using both crack and crevice nozzle 14915 and B & G 100 C.C. tip extension showed that cockroach mortality decreased as nozzle height increased. Highest cockroach mortality resulted when the nozzle height was 4 mm inside the crack. The lowest cockroach mortality occurred at the highest height of 150 mm above the crack. Possibilities for the decrease in cockroach mortality as nozzle height increased was attributed to two factors. First, air turbulance intensified as nozzle height increased resulting in greater chance for particle drift. Secondly, nozzle guidance became more difficult due to the added height and magnification of the nozzle stand vibration. Combination of particle drift and poor nozzle guidance reduced the degree of spray coverage from complete to broken coverage. Either of these factors would be important for practical spray application since they could result in environmental contamination. The contamination would result from drift or runoff reducing the amount of spray deposited

Figure 16. Nozzle Height: A Graphic Illustration Derived from Table 4 Depicting Mean Mortality of *Blatella germanica* over a Twenty-one Day Period Increasing Crack Width and Nozzle Height


B&G Nozzle
Nozzle 14915
Nozzle 800067
Number Of Dead Cockroaches
Crack Width
5 mm
2 mm
0
1
2
3
4
5
-4mm
5mm
150mm
Nozzle Height

inside the crack.

Cockroach mortality remained relatively constant for all treatment combinations using the fan nozzle 800067. This consistently was due to the relatively same amount of chemical being deposited inside the crack at both nozzle heights due to the fan spray width. The majority of the spray was deposited outside the crack.

A gradual decrease in cockroach mortality resulted as the days following treatment increased. The analysis of variance showed a significant difference in cockroach mortality over the twenty-one day period following treatment. Figure 17 depicts average cockroach mortality of all treatment combinations (varying nozzle type, nozzle height, and crack width) at an interval of 1, 7, 14, and 21 days following treatment.

The highest mortality for all treatments with the different nozzles occurred one day following spraying. The lowest mortality occurred twenty-one days after spraying, except for the average mortality of the nozzles at two treatment combinations. The cockroach average kill for the nozzles at a nozzle height of 150 mm and a crack width of 2 mm seven days following treatment was .11 cockroaches. The average cockroach kill for the nozzles at a nozzle height of 5 mm and a crack width of 5 mm, fourteen days following treatment was one cockroach. Under the above test condition, the lower kills could possibly have been due to a poor degree of spray coverage inside the crack or the cockroaches' ability to avoid the treated surface.

Cockroach mortality resulting from the crack and crevice nozzles' treatment combination over a twenty-one day period is represented in Figure 18. The trend was the same as for the previous test where

Figure 17. Days after Treatment: A Graphic Illustration Derived from Table 6 Depicting Average Mortality Levels of *Blatella germanica* at Intervals of 1, 7, 14, and 21 days after Treatment Increasing Crack Width and Nozzle Height

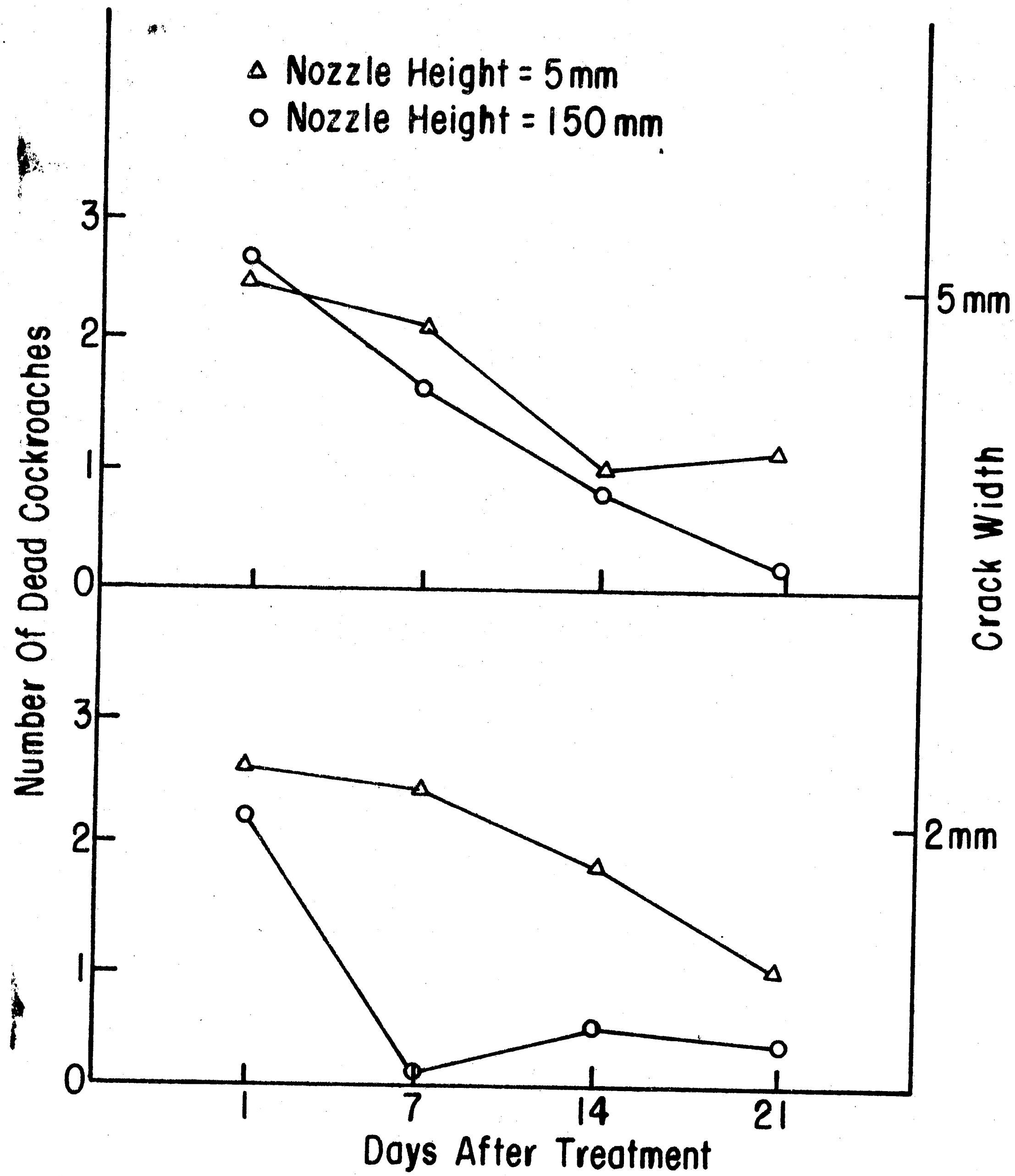
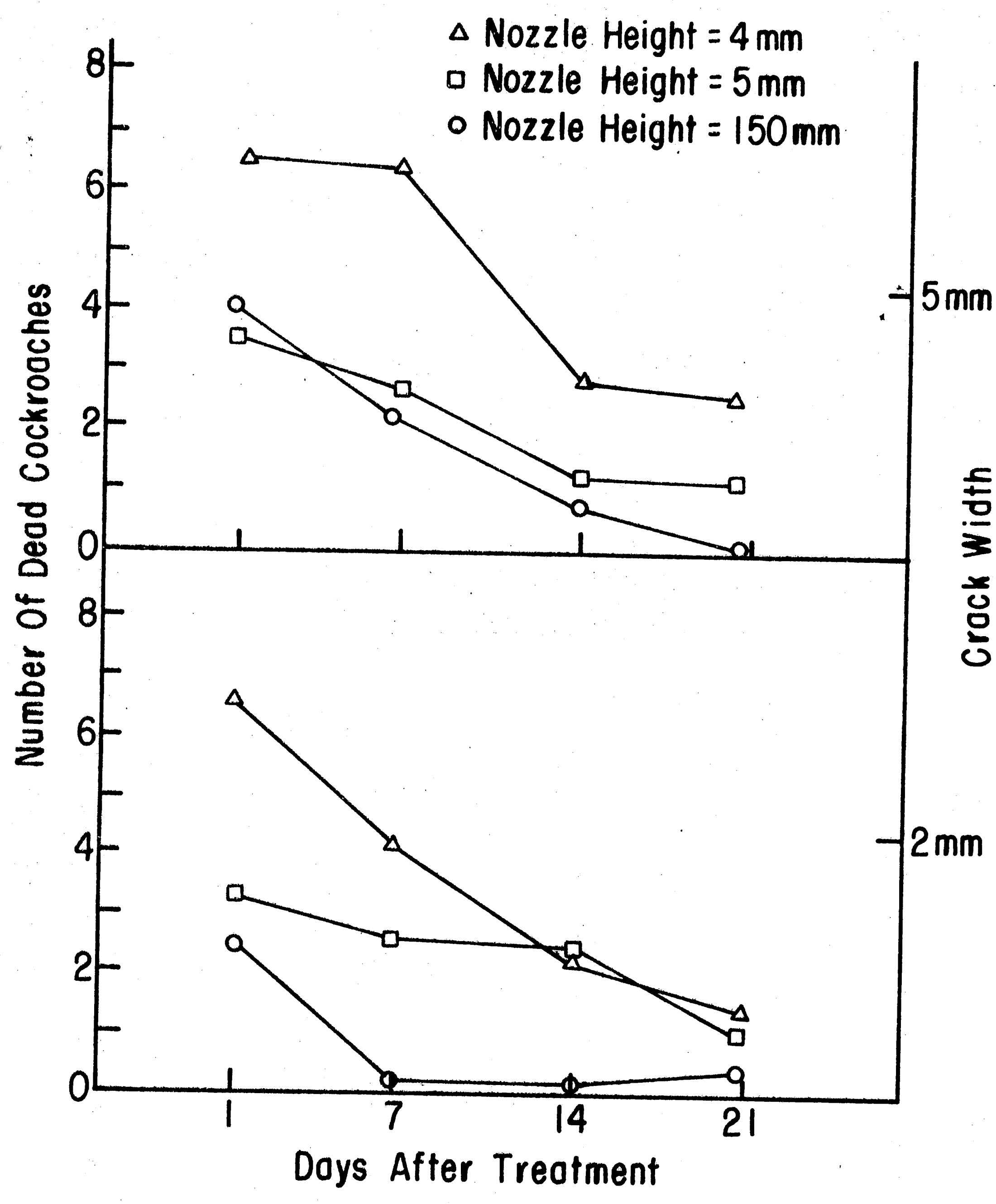

△ Nozzle Height = 5 mm
○ Nozzle Height = 150 mm
Number Of Dead Cockroaches
3
2
1
0
3
2
1
0
1
7
14
21
Days After Treatment
5 mm
2 mm
Crack Width

Figure 18. Days after Treatment: A Graphic Illustration from Table 7 Depicting Crack and Crevice Nozzles' Average Mortality Levels of Blatella germanica at Intervals of 1, 7, 14 and 21 days after Treatment while Increasing Crack Width and Nozzle Height



Nozzle Height = 4 mm
Nozzle Height = 5 mm
Nozzle Height = 150 mm
Number Of Dead Cockroaches
Crack Width
5 mm
2 mm
8
6
4
2
0
8
6
4
2
0
1
7
14
21
Days After Treatment

there was a decrease in cockroach mortality over time. One exception occurred twenty-one days following treatment at a nozzle height of 150 mm and a crack width of 2 mm. The average number killed was .50 cockroaches.

Correlation Between Degree of Coverage and Blatella germanica Mortality Levels

The degree of spray coverage was determined by visual observation using fluorescent dye and a black light. A target area was marked on the two surface plates to help aid in determining the amount of spray being deposited outside the crack. Three types of degree of coverage could have resulted from the crack and crevice treatment. These were complete, broken, or completely missed. Complete degree of coverage refers to the direct placement of all the spray inside the crack. Partial spray placement inside and outside the crack means the degree of coverage is broken. Completely missed degree of coverage shows no spray being deposited inside the crack. The number of each type of spray coverage resulting from each nozzle combination is illustrated in Table 8. All twelve spray treatment combinations using the crack and crevice nozzles, B & G 100 C.C. tip extension, and Spraying Systems nozzle 14915 were complete when inserted into the crack at a nozzle height of 4 mm. As the nozzle height increased above the crack, the number of spray treatments that were complete decreased. At a nozzle height of 5 mm, seven out of the twelve spray treatment combinations were complete. The other five treatments had broken coverage. Broken degree of coverage dominated the type of coverage at the highest nozzle height of 150 mm. All twelve treatment combinations had a broken degree of coverage. All twelve treatment combinations using the fan nozzle 800067 had a broken degree of coverage. No completely missed spray patterns were observed throughout the test.

The extent of cockroach mortality is affected by the degree of spray coverage. The average cockroach mortality by each nozzle when varying nozzle height and crack width is represented in Table 4. Comparing Table 8 with Table 4, higher cockroach mortality resulted when the degree of coverage was complete. With both crack and crevice nozzles, cockroach mortality decreased as the nozzle height increased. As nozzle height increased, the degree of coverage became broken. Figure 19 shows a complete spray pattern which resulted from crack treatment 4 mm inside the crack with a B & G 100 C.C. tip extension. Virtually all the spray was deposited inside the crack which increased the chances for the cockroaches to come into contact with the insecticide. Less spray was deposited inside the crack at a nozzle height of 150 mm above the crack using nozzle 14915 (Figure 20). This reduction in the amount of spray deposits inside the crack increased the chances for cockroaches to avoid contact with the insecticide reducing mortality levels.

The degree of spray coverage and cockroach mortaltiy remained relatively constant for nozzle 800067 for all treatment combinations. Comparing the broken spray pattern of nozzle 800067 at 5 mm (Figure 21) and the broken spray pattern at 150 mm (Figure 22) showed that the amount of insecticide deposited inside the crack and outside the crack remained constant. The only difference was the area of contamination outside the crack which was due to the increase in the spray band width at 150 mm.

Figure 19. Complete Spray Pattern of the B & G Nozzle at a Height of - 4 mm and a Crack Width of 5 mm

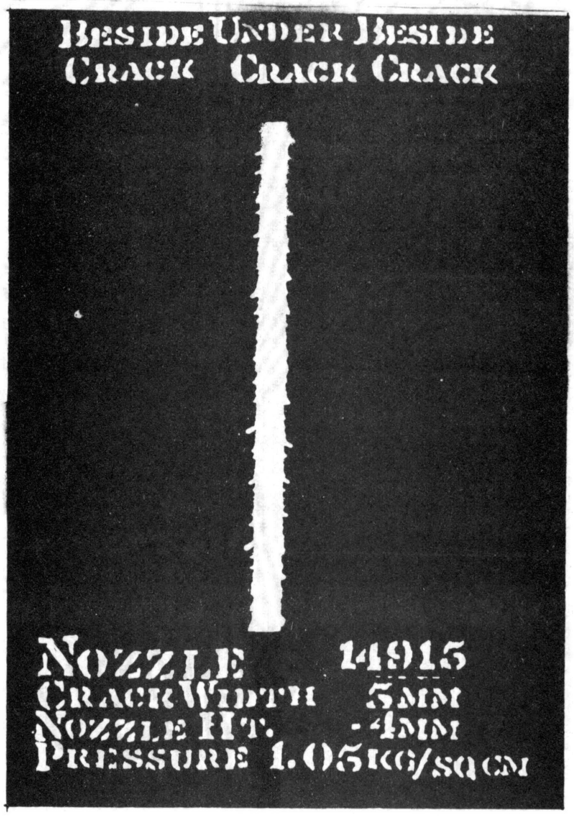

BESIDE UNDER BESIDE
CRACK CRACK CRACK
NOZZLE 14915
CRACK WIDTH 5MM
NOZZLE HT. -4MM
PRESSURE 1.05KG/SQCM

Figure 20. Broken Spray Pattern of Nozzle 14915 at a Height of 150 mm and a Crack Width of 5 mm

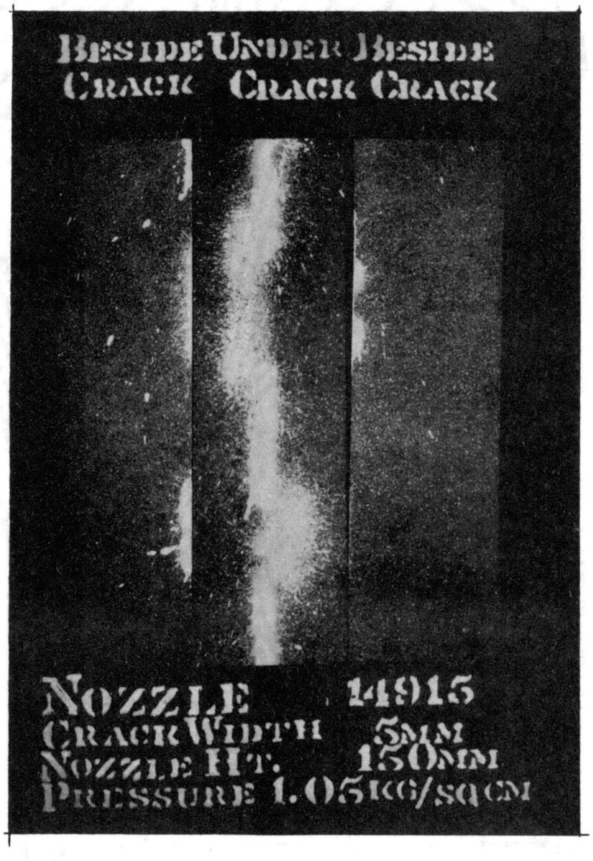

BESIDE UNDER BESIDE
CRACK CRACK CRACK
NOZZLE 14915
CRACK WIDTH 5MM
NOZZLE HT. 150MM
PRESSURE 1.05KG/SQ CM

Figure 21. Broken Spray Pattern of Nozzle 800067 at a Height of 5 mm and a Crack Width of 5 mm

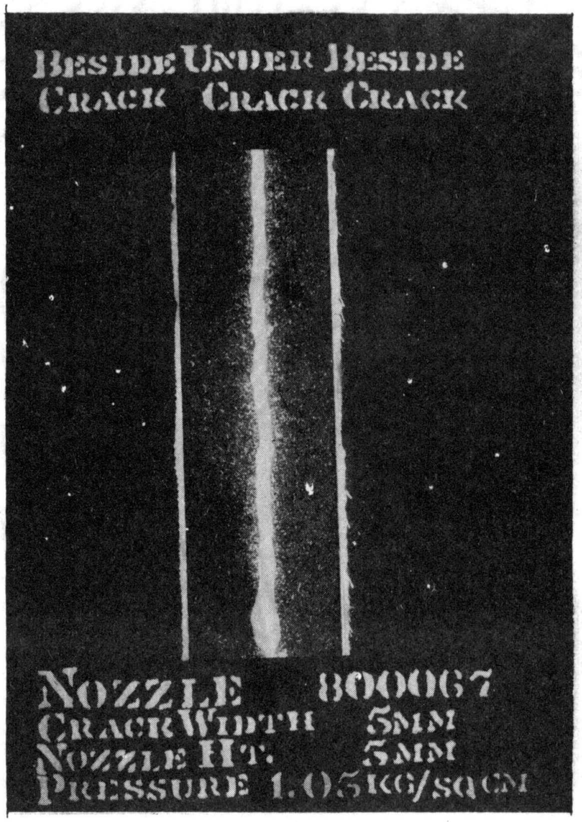
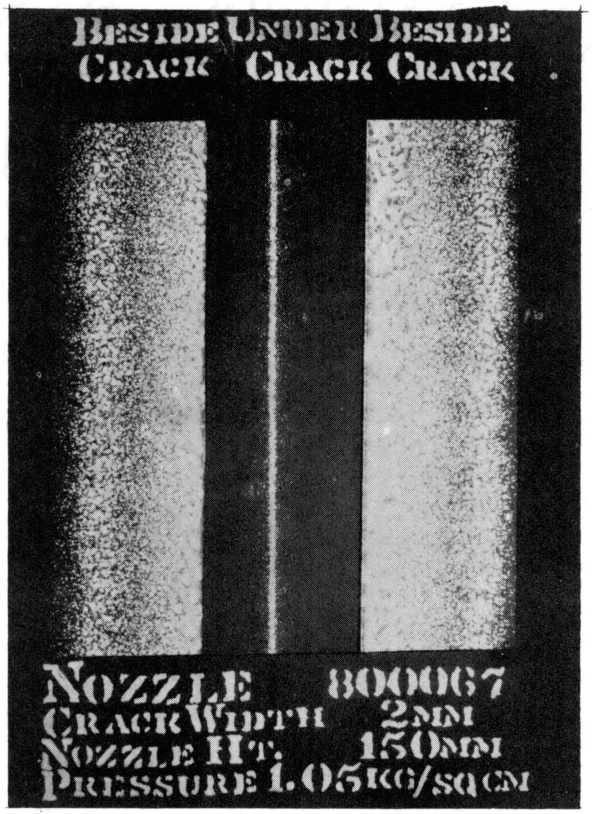

BESIDE CRACK
UNDER CRACK
BESIDE CRACK
NOZZLE 800067
CRACK WIDTH 5MM
NOZZLE HT. 5MM
PRESSURE 1.05KG/SQCM

Figure 22. Broken Spray Pattern of Nozzle 800067 at a Height of 150 mm and a Crack Width of 2 mm


BESIDE UNDER BESIDE
CRACK CRACK CRACK
NOZZLE 800067
CRACK WIDTH 2MM
NOZZLE HT. 150MM
PRESSURE 1.05KG/SQCM

The major cause of broken degree of spray coverage when treating cracks and crevices was due to improper guidance. Improper guidance in treatment of cracks and crevices in commercial and industrial eatablishments could result in considerable contamination to non-target areas. In addition to the danger of environmental contamination, PCO costs could increase due to excessive spray waste.

Validity of Test Results

Untreated cockroaches' mortality level during the test is shown in Table 9. Only two cockroaches died during the test. Two possibilities for the deaths could be the handling procedure or natural causes. The low cockroach mortality that resulted in the control test would tend to indicate that cockroach mortality in the treatment test was due to insecticide toxicity and not to handling procedures.

CHAPTER V

CONCLUSION

Effects of Nozzle Type, Nozzle Height, and Crack Width on *Blatella germanica* Mortality Over a Twenty-one Day Period

The results obtained in this study using simulated crack and crevice treatment indicated that the type of nozzle used by PCO's affect cockroach control. Treatment combination with nozzle 800067 did not show significant cockroach kill. Inadequate cockroach control by crack and crevice treatment using this nozzle is due to the fan spray pattern. At all nozzle heights the majority of the insecticide was deposited outside the crack opening, resulting in a poor degree of coverage inside the crack. Both crack and crevice nozzles, B & G 100 C.C. tip extension, and Spraying Systems 14915 significantly out performed nozzle 800067. No significant difference was indicated between crack and crevice nozzles in the analysis of variances. Possibilities for greater cockroach control could be due to the fact that both crack and crevice nozzles were pin streams, allowing for a complete degree of spray coverage inside the crack when the nozzle was directly over the crack's opening. Treating cracks and crevices, PCO's may want to consider using nozzles designed similarly to the crack and crevice nozzles used in the test due to the inadequate cockroach control obtained using the fan nozzle 800067.

The extent of cockroach control was greatly affected by the nozzle height. This was evident from test results which showed that an increase in nozzle height resulting in a decrease in cockroach mortality results. The highest mortality resulted after inserting both crack and crevice nozzles inside the crack at a height of 4 mm. The lowest number killed occurred when all nozzles were at a height of 150 mm above the crack. The decrease in cockroach mortality with an increase in height was related to the degree of spray coverage inside the crack. As nozzle height increased, the degree of spray coverage was reduced from a complete coverage at 4 mm inside the crack to a broken coverage at 150 mm above the crack. The difference in the degree of spray coverage at the various nozzle heights was mainly due to the nozzle guidance. As the height increased, it became more difficult to accurately guide the nozzle directly over the crack opening.

Crack width did not influence the number of cockroaches killed at any one treatment combination during the test. Crack width could affect the extent of control when the crack width is smaller than the diameter of the nozzle tip (2 mm). Not allowing the nozzle to be inserted into the crack could possibly reduce cockroach control due to inadequate penetration of insecticide (spray coverage inside the crack).

Cockroach mortality for treatment combinations generally decreased as the days after treatment increased. Mortality rates for the cockroaches were highest one day after treatment and lowest twenty-one days after treatment. Toxicological research indicated that insecticide potential effected by three factors. The first factor is (1) contact and uptake of insecticide into the insect, (2) metabolic activities of the insect and acceleration or degradation of the insecticide, (3) environmental factors, such as temperature and humidity directly influencing the degradation of the insecticide by hydrolysis or indirectly by increasing the metabolic activities of the insect. Exposure of the insecticide to the environment over a period of time was probably the major cause for the decrease in cockroach mortality for all nozzle treatment combinations over time.

Correlation Between Degree of Coverage and *Blatella germanica* Mortality

The number of cockroaches killed in each treatment combination was directly correlated to degree of spray coverage inside the crack. The highest cockroach mortality occurred when the spray coverage was complete. Complete spray coverage refers to depositing all the insecticide inside the crack. All treatment combinations of both crack and crevice nozzles had complete spray coverage with the nozzle tip inserted at 4 mm inside the crack. As nozzle height increased, the degree of spray pattern coverage changed from complete coverage to broken coverage, mortality levels decreased. The lowest cockroach mortality for both crack and crevice nozzles resulted at a nozzle height of 150 mm. With this increase in height and decrease in spray pattern coverage the cockroach had a greater chance to avoid the insecticide, resulting in lower mortality levels.

Cockroach mortality level using nozzle 800067 remained relatively low throughout the test. This was attributed to the lack of the insecticide deposited inside the crack, which was caused by the fan spray pattern of the nozzle. Due to the nozzle spray width, the insecticide was not concentrated at the crack opening. The majority of the insecticide was deposited outside the crack. The degree of spray coverage from all treatment combinations was broken. The only difference in the degree of spray coverage at the two heights was the width of the spray band. As the nozzle height increased, the spray band width increased. This waste of insecticide outside the crack resulted in an increase in environmental contamination and application costs, attributed to poor cockroach control.

Summary and Area of Future Research

Effectiveness of crack and crevice treatment in controlling cockroaches was determined by the degree of spray coverage inside the crack. Many factors, such as nozzle guidance, nozzle type, and nozzle height, influence the degree of spray coverage. The use of a motorized track and a nozzle stand, rather than hand operated guidance; assured accurate nozzle guidance at all nozzle heights. PCO's could increase the degree of spray coverage inside the crack by applying the results of this study. A nozzle designed for crack and crevice treatment should be used and the tip should be inserted inside the crack. In addition a reduction of tank pressure and application speed would insure proper nozzle guidance. Proper nozzle guidance would result in a complete degree of spray coverage inside the crack which would reduce the chance of environmental contamination.

Future research possibilities are to improve spraying techniques, and try to develop methods to treat cracks and crevices.

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APPENDIX

TABLE 1

CALIBRATION AND CONVERSION TABLE FOR THREE NOZZLES TO DETERMINE APPLICATION SPEED TO DEPOSIT A CONSTANT VOLUME OF LIQUID

1. Spraying System Multi-Teejet® 800067

Pressure (kg/cm^2)	Volume (ml)[a]	Speed (cm/sec)[b]
1.05	5.25	55.64
1.38[c]	7.25	76.82
2.10	9.75	97.91

2. Spraying System Crack and Crevice 14915

Pressure (kg/cm^2)	Volume (ml)	Speed (cm/sec)
1.05	8.25	87.34
2.10	13.75	145.14

3. B & G 100 C.C. Crack and Crevice Tip Extension

Pressure (kg/cm^2)	Volume (ml)	Speed (cm/sec)
1.05	5.25	55.64
2.10	6.75	70.92

[a]Average of three volumes collected in two seconds

[b]Speeds calculated by the formula

$$\text{standard}\ \left(\frac{76.82\ \text{cm/sec}}{7.25\ \text{ml}}\right) \times \frac{x}{\text{Volume of Various Nozzles}}$$

[c]Rogers® (1973) most effective spray pattern resulting from a Multi-Teejet® 800067 at a pressure (1.38 kg/cm^2) and a speed (76.82 cm/sec) used as a standard.

TABLE 2

ANALYSIS OF VARIANCE OF BLATELLA GERMANICA MORTALITY UTILIZING THREE NOZZLE TYPES, TWO CRACK WIDTHS, AND TWO NOZZLE HEIGHTS

Source of Variance	DF	SS	MS	F Value	Prob F
Replication	2	.265884	.1319444		
Nozzle	2	48.722222	24.3611111	10.88519	0.0006
Height	1	24.173611	24.1736111	10.80141	0.0036
Nozzle*Height	2	5.055556	2.5277778	1.12948	0.3420
Width	1	0.340278	0.3402778	0.15205	0.7018
Nozzle*Width	2	3.388889	1.6944444	0.75712	0.5152
Width*Height	1	8.506944	8.5069444	3.80113	0.061
Nozzle*Width*Height	2	11.555556	5.7777778	2.58166	0.0968
Day	3	72.131944	24.0439815	12.80764	0.0001
Nozzle*Day	6	30.055556	5.0092593	2.66831	0.0213
Height*Day	3	7.409722	2.4699074	1.31566	0.2751
Nozzle*Height*Day	6	5.277778	0.8796296	0.46856	0.8304
Width*Day	3	2.909722	0.9699074	0.51665	0.6764
Nozzle*Width*Day	6	20.944444	3.4907407	1.86954	0.0991
Width*Height*Day	3	7.409722	2.4699074	1.31566	0.2751
Nozzle*Width*Height*Day	6	5.444444	0.9074074	0.48335	0.8198

TABLE 3

ANALYSIS OF VARIANCE OF *BLATELLA GERMANICA* MORTALITY COMPARING ONLY CRACK AND CREVICE NOZZLE AT TWO CRACK WIDTHS AND THREE NOZZLE HEIGHTS

Source of Variance	DF	SS	MS	F Value	Prob F
Replication	2	5.791667	2.8988333		
Nozzle	1	0.111111	0.1111111	0.03250	0.8527
Height	2	190.166667	95.0833333	27.81385	0.0001
Nozzle*Height	2	0.388889	0.1944444	0.05688	0.9447
Width	1	9.000000	9.0000000	2.63269	0.115
Nozzle*Width	1	0.111111	0.1111111	0.03250	0.8527
Width*Height	2	21.500000	10.7500000	3.14460	0.0616
Nozzle*Width*Height	2	4.222222	2.1111111	0.61754	0.5528
Day	3	223.500000	74.5000000	32.90798	0.0001
Nozzle*Day	3	7.611111	2.5370370	1.12065	0.3467
Height*Day	6	35.666667	5.9444444	2.62577	0.0231
Nozzle*Height*Day	6	6.555556	1.0925926	0.48262	0.8302
Width*Day	3	8.722222	2.9074974	1.28425	0.2856
Nozzle*Width*Day	3	15.388889	5.1296296	2.26585	0.0868
Width*Height*Day	6	14.444444	2.4074074	1.06339	0.3928
Nozzle*Width*Height*Day	6	16.611111	2.7685185	1.22290	0.3041

TABLE 4

AVERAGE MORTALITY[1] OF BLATELLA GERMANICA[2] OVER A TWENTY-ONE DAY PERIOD USING EACH NOZZLE VARYING CRACK WIDTH AND NOZZLE HEIGHT

Crack Width	Nozzle Height	Nozzles			Untreated[3] Check
		800067	B&G	14915	
2 mm	- 4 mm	-	3.41	4.0	.11
2 mm	5 mm	.83	2.83	2.66	.11
2 mm	150 mm	.83	1.00	.58	.11
5 mm	- 4 mm	-	4.83	4.41	.11
5 mm	5 mm	.83	2.25	2.08	.11
5 mm	150 mm	.25	1.83	2.08	.11

[1]Average number killed during three replications.

[2]Ten cockroaches released per treatment combination.

[3]Forty cockroaches released per treatment interval, 160 cockroaches per replication.

TABLE 5

TOTAL *BLATELLA GERMANICA* MORTALITY[1] OVER A TWENTY-ONE DAY PERIOD USING THREE TYPES OF NOZZLES, UTILIZING TWO CRACK WIDTHS AND TWO NOZZLE HEIGHTS

Crack Width	Nozzle Height			Untreated Check[4]
	- 4 mm[2]	5 mm[3]	150 mm[3]	
2 mm	29.5	21.97	9.67	1
5 mm	36.7	20.61	16.63	1

[1]Total mortality of 3 replications, total of 120 cockroaches exposed to treated surface.

[2]Total mortality of the two crack and crevice nozzles.

[3]Total mortality of the fan nozzle and the crack and crevice nozzles.

[4]Total mortality of the untreated check, total of 160 cockroach per replication, total of 480 cockroaches used.

TABLE 6

TOTAL MORTALITY[1] OF BLATELLA GERMANICA[2] AFTER EXPOSURE AT INTERVALS OF 1, 7, 14, AND 21 DAYS AFTER TREATMENT VARYING CRACK WIDTH AND NOZZLE HEIGHT

Crack Width	Nozzle Height	Days			
		1	7	14	21
2 mm	5 mm	2.77	2.66	1.88	1.11
2 mm	150 mm	2.33	.11	.44	.33
5 mm	5 mm	2.55	2.11	1.00	1.22
5 mm	150 mm	2.66	1.77	.88	.22
Untreated Check[3]		.33	.33	0	0

[1]Average of the three nozzles' mortality killed, replicated three times.

[2]Ten cockroaches released per treatment combination.

[3]Forty cockroaches released per treatment combination, replicated three times.

TABLE 7

AVERAGE MORTALITY[1] OF BLATELLA GERMANICA[2] USING CRACK AND CREVICE NOZZLES AFTER EXPOSURE AT INTERVALS OF 1, 7, 14 AND 21 DAYS AFTER TREATMENT VARYING CRACK WIDTH AND NOZZLE HEIGHT

Crack Width	Nozzle Height	Days			
		1	7	14	21
2 mm	- 4 mm	6.66	4.16	2.16	1.83
2 mm	5 mm	3.33	2.66	2.33	1.66
2 mm	150 mm	2.33	.16	.16	.50
5 mm	- 4 mm	6.50	6.50	3.00	2.50
5 mm	5 mm	3.50	2.83	1.16	1.16
5 mm	150 mm	4.00	2.50	1.00	.33
Untreated Check[3]		.33	.33	0	0

[1]Combined average of both crack and crevice nozzles' mortality levels replicated three times.

[2]Ten cockroaches released per treatment combination.

[3]Forty cockroaches released per treatment combination replicated three times.

TABLE 8

TYPE AND NUMBER[1] OF SPRAY PATTERNS USING THREE NOZZLES VARYING CRACK WIDTH AND NOZZLE HEIGHT

Nozzle Type	Crack Width	Nozzle Height	Type of Coverage		
			Complete	Broken	Missed
Fan	2 mm	5 mm	0	3	0
	2 mm	150 mm	0	3	0
	5 mm	5 mm	0	3	0
	5 mm	150 mm	0	3	0
14915	2 mm	- 4 mm	3	0	0
	2 mm	5 mm	3	0	0
	2 mm	150 mm	0	3	0
	5 mm	- 4 mm	3	0	0
	5 mm	5 mm	3	0	0
	5 mm	150 mm	0	3	0
B&G	2 mm	- 4 mm	3	0	0
	2 mm	5 mm	1	2	0
	2 mm	150 mm	0	3	0
	5 mm	- 4 mm	3	0	0
	5 mm	5 mm	1	2	0
	5 mm	150 mm	0	3	0

[1]Total number of spray patterns equals three - one per replication.

TABLE 9

NUMBER OF DEAD *BLATELLA GERMANICA* PER UNTREATED CHECK[1] PER REPLICATION

Replication	Day	Number Dead
1	1	1
	7	0
	14	0
	21	0
2	1	0
	7	0
	14	0
	21	0
3	1	0
	7	1
	14	0
	21	0

[1]Each untreated check consisted of forty cockroaches - total of 160 cockroaches per replication.

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Master of Science

Thesis: A LABORATORY EVALUATION OF CRACK AND CREVICE TREATMENTS FOR CONTROL OF THE GERMAN COCKROACH, BLATELLA GERMANICA (LINNEAUS), USING VARIOUS NOZZLE TYPES, NOZZLE HEIGHTS, AND CRACK WIDTHS

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