A LABORATORY EVALUATION OF TEST APPARATUS AND TECHNIQUES FOR INVESTIGATING SPRAY DEPOSIT AND DRIFT IN CRACK AND CREVICE TREATMENT

By

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A LABORATORY EVALUATION OF TEST APPARATUS AND TECHNIQUES FOR INVESTIGATING SPRAY DEPOSIT AND DRIFT IN CRACK AND CREVICE TREATMENT

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CHAPTER I

INTRODUCTION

There has been much discussion in recent years about the use of chemicals in pest control. Much of this concern is about the amount and placement of chemicals used in and around the home and commercial establishments for pest control. In this era of increased cost, the most efficient control per amount of chemical used is a matter of economics as well as safety.

There is very little data available on the movement of insecticides from the point of application to non-target areas. Methods utilized at present are not as accurate as is desired. Research is being conducted constantly to improve techniques and equipment that are available. Presently it is possible to determine residues, picture drift, calculate output, and determine amount of deposit of insecticide in most surface applications.

One area has been largely neglected. This area is that of crack and crevice treatments. There have been few studies conducted on the movement of insecticides into and out of cracks and crevices. With the new regulations of the Environmental Protection Agency (EPA) much emphasis is being placed on the use of crack and crevice treatments. The EPA's accepted definition of crack and crevice is "Expansion joints between different elements of construction or the area between equipment bases and the floor, wall voids, motor housing, junction boxes or switch

boxes, conduits, or hollow equipment legs where cockroaches, crickets, firebrats, silverfish, and spiders hide."[1]

Methods and equipment are not yet developed that can give an accurate estimate of insecticide placement, drift, and residuals in cracks and crevices. Older methods are not adequate since insecticides are generally injected in cracks and crevices. There is no way, at this time, to measure insecticide penetration, deposit, and volatilization. The lack of information concerning the actions of insecticides in crack and crevice treatments led this researcher to search for more precise methods of determining physical movement and action of insecticide in the areas previously mentioned.

To determine whether a new treatment, chemical, or new application method is to be useful in pest control, two types of studies must be conducted: a laboratory examination of the treatment's effect on insects, and a study of it in the field under controlled conditions. To determine how a treatment can be used most advantageously, it is necessary to make a detailed study of its effect qualitatively and quantitatively. This can most accurately be done in the laboratory under controlled conditions.

The objective of this study was to develop and test apparatus to be used in assessing insecticide movement, drift, and deposition in crack and crevice treatments.

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[1]Taken from Label 86-1176 for DURSBAN^{R} 2E Insecticide, The Dow Chemical Company, Midland, Michigan.

CHAPTER II

LITERATURE REVIEW

Early Research in the Study of Insecticide Effectiveness

In the 1930's much research was done in an effort to increase knowledge of contact insecticides, determine their action, and improve application techniques for better control of household insect pests. There were many methods of studying the action of contact insecticides, all of which depended on spraying a known amount of insecticide at a definite pressure, from a certain height, on selected insects. Placing the insecticide on the target insect was the emphasis. Insecticides that had a strong residual while being relatively safe were not yet available; thus the emphasis was on contact insecticides.

Many of the methods used at that time lacked accuracy. Results could not be repeated as is required in scientific work. Bradertscher (1936) showed that not only many different results could be obtained with the Peet-Grady Method (1928) and the Campbell "Turn-Table" Method (1938), two widely accepted test procedures, but that the differences in insecticides had a different order of relative toxicity by the two test methods and by replicate test using the same methods. Shepard and Richardson (1931) devised a dipping method which Craufurd-Benson (1938) modified. This modified method of contact insecticide application increased accuracy but was far removed from application conditions and

results produced in the laboratory were often not the same as those found in field tests. Shepard (1951) describes how the study of insecticides have evolved from the study of the arsenates as stomach poisons to the complex study of surface-active phenomona and its effect on droplet deposition.

Evolution of Apparatus

When it became necessary to devise a laboratory spraying apparatus suitable for testing insecticides, Potter (1941) used the Tattersfield apparatus (1939) as a starting point since it was the only spray apparatus whose performance had been fully investigated and published at that time. Potter improved the design of Tatterfield's atomizing nozzle and used a spraying tower to get a fairly even deposit of droplets on a 6-inch plate. Using his apparatus, Potter was able to get his variation in the total deposit, in a series of spraying trials, down to 10 to 20%.

Hewlett (1946) worked on improving the design of the atomizing nozzle. His nozzle had several advantages over Potter's nozzle. The nozzle settings could be repeated, the inner cone to outer cone distance could be adjusted, and reset by means of an adjusting screw. In addition to this, the centering of the inner cone was controlled by a screw device. With these improvements, the nozzle could be disassembled for cleaning and reset to the same setting for the next insecticide test.

Study of Deposition

The comprehensive study of deposition began after some degree of duplication was established in test nozzles. Glasgow (1947) pointed out

that smaller droplets covered a larger area than the equivalent amount of the same chemical when dispersed as large droplets. Potter (1946) showed that the finer the atomization the less spray was required to cover a given area. However with finer atomization and less volume, it was necessary to increase the concentration of the spray to obtain an adequate dosage rate. This was the same thing that Lindquist et al. (1945) had observed in control of houseflies and mosquitos in the home.

Potts (1946) studied particle sizes of insecticides applied as dusts, oil-coated dusts, and concentrated sprays. He concluded that droplet sizes have a major effect on the amount of insecticide deposited. In addition he found that many factors affect droplet sizes including concentration and type of distribution device. Potter (1941) found that atmospheric conditions such as humidity and temperature also effect deposition.

Yoemans and Rogers (1953) described a simple procedure to study the deposit of various sprays. He determined droplet sizes by exposing a coated microscope slide in a spray as it was directed downward using the Waved Slide Method described by Yoemans (1949). He was also able to calculate the percentage of spray material deposited by spraying absorbent paper that had been weighed before and after application of insecticide.

Study of Residues

Recommendations of State and Federal agencies suggest that all food, dishes, and all utensils be removed from areas being treated for insect pests (Anonymous 1968). The implication was that residues would be deposited on the items if they were not removed. However, evidence of

this was lacking. Wright and Jackson (1971), using very accurate equipment, analyzed the amount of propoxur, chlordane, and diazinon deposits on dishes during application of insecticides in a kitchen cabinet. They found that insecticide residues were greatly reduced on day after treatment and that the maximum amount found on the top saucer of a set of sauces was 1/1000 of the LD_{50} for white rats.

Shore (1974) used mathematics to estimate the amount of insecticide that would be sprayed with resulting residue in crack and crevice treatments. His work was theoretical as it was based on several assumptions that have not been substantiated. Shore set forth three hypotheses:

(1) Toxic materials last longer in cracks and crevices.

(2) Roaches pick up toxic material at a faster rate in cracks and crevices.

(3) Insecticide sprayed into a crack and crevice will build thicker toxic film than when sprayed onto a flat surface.

Wright and Jackson (1975) studied deposit of insecticide residues in non-target areas after crack and crevice treatment using aerosol-type and compressed air sprayers. Their study showed significantly less movement of insecticides to non-target areas with the aerosol-type sprayer than with the compressed air sprayer.

Lykken (1967) and Keil et al. (1969) studied the danger of pesticide usage in the home. These studies indicated that in household insecticide applications, occupants often fail to follow proper safety practices. This fact and the lack of knowledge concerning the deposition of residues of some persistant insecticides lead to the banning of use of certain insecticides except in crack and crevice treatments. The National Pest Control Association (1972) pointed out the need for more

study in the area of crack and crevice treatments. Shore (1974) also pointed out the need for more study in this area.

CHAPTER III

METHODS AND MATERIALS

For this test, application equipment commonly used by pest control operators was modified to use with the test apparatus designed by this researcher. A Spraying Systems Multi-Teejet® Nozzle[1] and a B & G Directa-Mist® Ultra Low Volume Sprayer[2] were used for application of the insecticide. The chemical used for testing the apparatus was analytical standard grade Alpha-Gamma Chlordane, ACS 3260, B #C-7022.[3]

Modification of Application Equipment

To provide Ultra Low Volume (ULV) and conventional spray capabilities a B & G Directa-Mist® ULV spray delivery system was modified. Modifications (Fig. 1) consisted of replacing the standard 3.785 liter stainless steel tank, which had an attached holder for a CO_2 cylinder, with a 3.785 liter B & G stainless steel tank model number 104-S. The pump assembly was replaced with a petcock, air regulator, air pressure gauge, and an outside air inlet. A second air pressure regulator, air gauge, and petcock were also added. The pump cylinder was also modified by cutting it in half and using the upper portion which is attached to

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[1] B & G Company, 10539 May Bank, P.O. Box 20372, Dallas, Texas.

[2] Ibid.

[3] Velsicol Chemical Corp., 341 East Ohio Street, Chicago, Illinois.

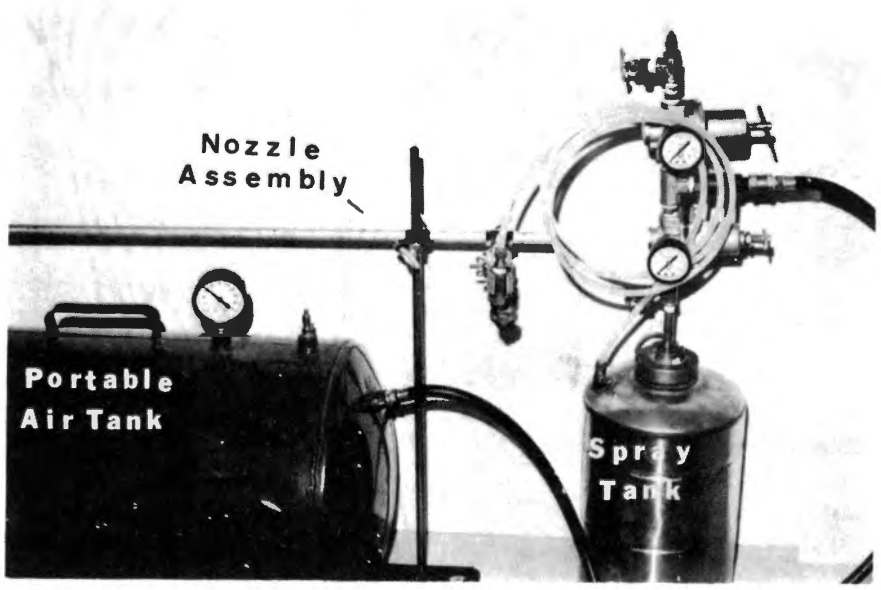

Figure 1. Application Equipment Showing Portable Air Supply Tank, Modified Spray Tank, and Nozzle Assembly

the brass cap. A 17.6 kg/sq cm portable air tank was used as the air supply source. These modifications allowed the sprayer tank pressure to be increased or lowered. The second air regulator and air gauge allowed the unit to be used for ULV spray application by a source of air for the air hose on the B & G ULV Ban-Drip valve. In addition it allowed for keeping pressure in the sprayer tank and the air hose constant while the spraying system was in operation. The ULV capabilities of this system were not utilized during this study. The liquid hose unit that was supplied with the Directa-Mist^{R} system was utilized.

A Multi-Teejet^{R} nozzle assembly (Fig. 2) was brazed to a modified buret clamp. A reduction body was added so that the small plastic hose from the Directa-Mist^{R} could be used. This nozzle assembly was attached to a horizontal bar which was attached to a ring stand using a clamp holder. By using clamps instead of fixed structures, nozzle to target distances and angle of spray adjustments were made possible. Once distance and angle were set, all clamps were tightened so that these factors would remain constant throughout the test. The angle and distance were checked prior to each run to see if any change had occurred. The entire assembly of nozzle and supporting structures was fastened to a traveling variable speed carrier to simulate moving application. This apparatus is described later.

Description of Test Apparatus

Base

The base (Fig. 3) was designed to support the "Base Plate" and the "Surface Plate". The base was constructed on sheet aluminum. A scissor jack was placed in the middle of the base to raise and lower the base

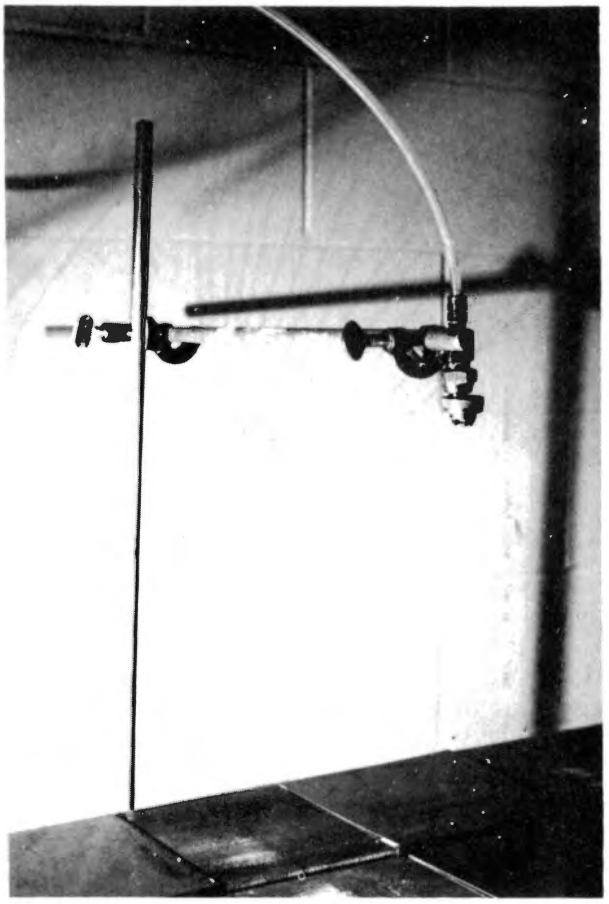

Figure 2. Modified Multi-Teejet® Nozzle Assembly

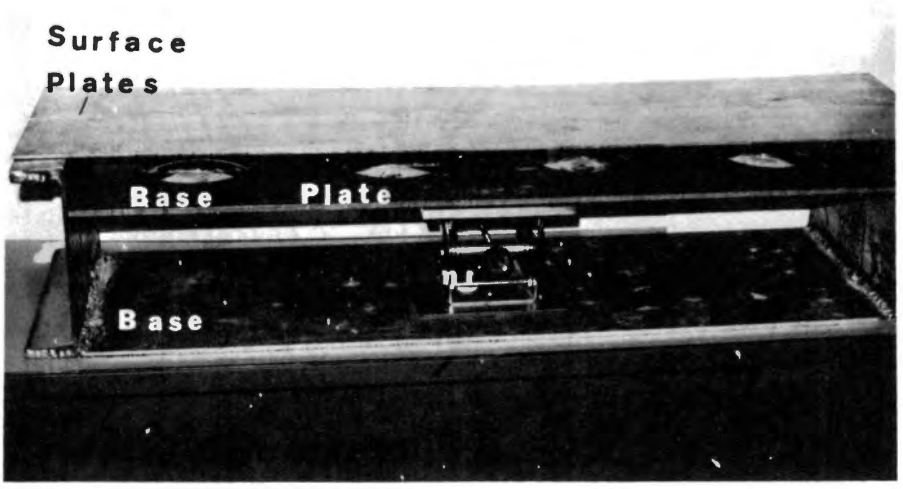

Figure 3. Side View of Test Apparatus Showing Base and Base Plate

plate. This raising and lowering facilitated the removal of the petri dishes and permitted the use of base plates of a different design for testing the effect of changing the inside area of cracks.

Base Plate

For this phase of the experimentation, the base plate (Fig. 3) was constructed to hold petri dishes that measures 15 X 150 mm (Fig. 4). When a different type of void (the area behind the crack opening, the shape of which could possibly affect insecticide deposit) is desired a different base plate can be used. The base plate was constructed of two strips of aluminum. One strip had four 15 cm holes placed in it to hold the petri dishes. The holes were 11 cm apart with 15 cm space at each end of the base plate. The four holes defined the sample areas. The second aluminum sheet was placed under the center of the top plate and served as a support for the petri dishes. The top level of the petri dishes was even with the top of the base plate.

Surface Plates

These two plates were made of sheet aluminum. Both surface plates (Fig. 5) had one straight edge that was used as the crack edge. Both surface plates were cleaned and buffed to remove scratches made during the cutting process. The surface plates served as a base for the four sample plates which collected the insecticide on the "outer" surface of the crack. The sample plates for the "vertical" surface of the crack were attached to the edge of the two surface plates.

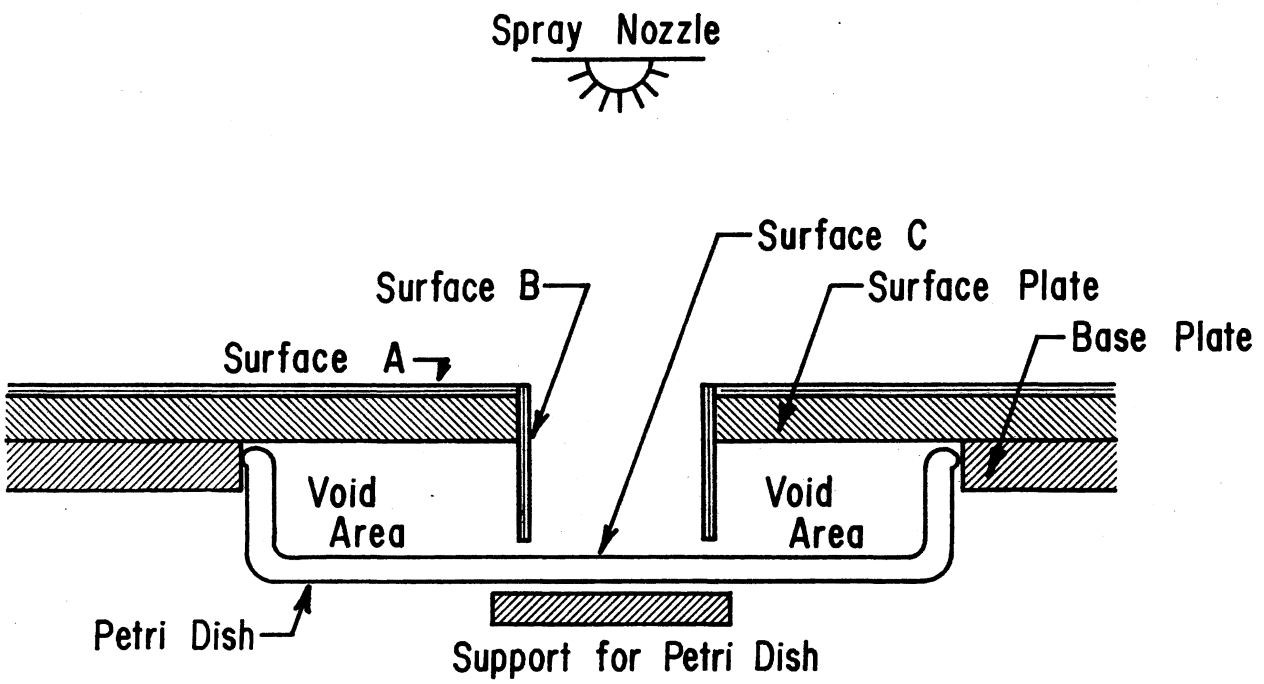

Figure 4. Cross Section of Test Apparatus Showing Surface Areas and Basic Structures

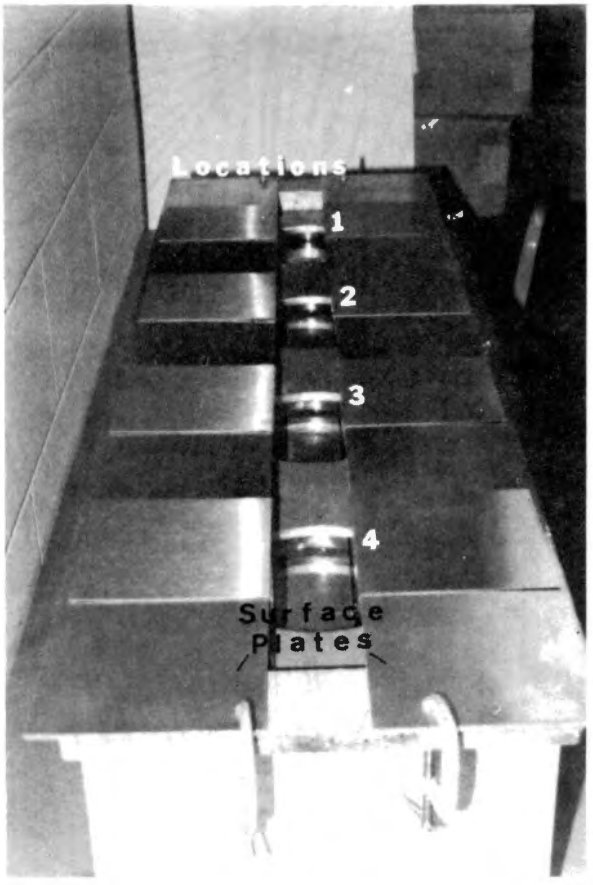

Figure 5. Top View of Test Apparatus Showing Surface Plates and Locations

Sample Areas

The test apparatus was designed such that there would be four sample areas or locations (Fig. 5) each 11 cm apart. There was an "outer" surface representing the outside of the crack (Surface A), a "vertical" surface representing the walls or sides of the crack (Surface B), and an "inner" surface (Surface C) representing the area behind the crack opening.

The surface-A plates were stainless steel plates that were machined to approximately 145 mm square. Each plate was measured and identified as to location--whether sample area 1, 2, 3, or 4. There were two sample plates for each sample area. The plates were cleaned and buffed to remove scratches made during machining.

The surface-B plates were also made of stainless steel. These plates were approximately 145 mm long, and 5, 10, 15, and 20 mm wide to create crack walls of those dimensions.

Surface C was a glass petri dish, 15 X 150 mm, one for each sample area. Petri dishes were used instead of stainless steel to permit their use at a later date in residual studies using cock-roaches.

Chromatographic Analysis

The amount of Chlordane in each collected sample was determined by injecting one microliter of each sample into a Hewlett-Packard Model 5750 gas chromatograph equipped with an electron capture detector. Ni 63 was the ionization source. The injector, column, and detector temperatures were 200, 200, and 240 degrees centigrade, respectively, for analysis of the chlordane deposits. A glass column (6.6 cm X 1.83 m) was used that was filled with 80 to 100 mesh chromosorb WAWDMCS coated with

3% silicon gum rubber, SE 30. The flow rate of the 5% methane-argon carrier gas was approximately 40 ml per minute. The method used for conversion of peaks to concentration was Absolute Calibration (McNair and Boneli, 1968). It involves using peak heights of known concentrations compared to the unknown concentrations of sample solutions. The standards were run at the beginning and end of analysis of each set of samples.

Pre-test Activities

Recovery Test

Recovery tests were run to determine how long the chemical would remain on the plate before a reduction due to volatilization could be observed and to determine the accuracy of the extraction technique being used. Solutions containing various concentrations of NANOGRADE benzene and Chlordane were prepared. The concentrations were 1, 10, and 100 ppm (vol.). One ml of these solutions was pipetted onto stainless steel plates and evaporated for varying lengths of time from 0 to 64 minutes. The plates were handled as they would be in studies on test apparatus. The chemical was washed from the plates using Nanograde benzene as a solvent. The recovery rate using this method, with evaporation times up to 64 minutes, averaged 99.88% with a range of 97 to 103%. The results of this study were not corrected for recovery.

Recovery Test: Glass vs. Stainless Steel

Since glass petri dishes and stainless plates were being used in this study, a test was designed to compare the recovery rates from glass and stainless steel. A standard solution of chlordane in a 10

ppm (vol.) concentration was prepared using Nanograde benzene as a solvent. One ml of the solution was pipetted onto the stainless steel plates and the petri dishes and evaporated for varying times up to 65 minutes. The chemical was then extracted from the plates and the dishes. Analysis showed less than a .03% variation between the glass and the stainless steel, when comparisons were made of samples that had the same length of evaporative time.

Storage of Samples for Extended Periods of Time

Standard solutions of 1, 10, and 100 ppm Chlordane-benzene solutions were stored at room temperature (20 degrees C) for 7 days and 14 days, in test tubes sealed with foil covered stoppers. When the stored solutions were analyzed and compared with samples made just prior to analysis, no decrease in composition could be determined. It appeared that as long as the solutions were kept sealed at relatively low temperatures, the chlordane-benzene solution was very stable.

Spraying Techniques

To prevent variation in spray pattern due to operator inconsistency, the nozzle assembly mounted on a ring stand was clamped to a track device (Fig. 6). This track device was developed by Oklahoma State University (OSU) Agricultural Engineers for use by the OSU Botany Department. The track device had a cart that was pulled along by a chain. The speed was adjustable and indicated by a calibrated speedometer. The power source for the track was supplied by an electric motor. The nozzle assembly was clamped to the cart. Distance and angle were set and remained constant throughout this study.

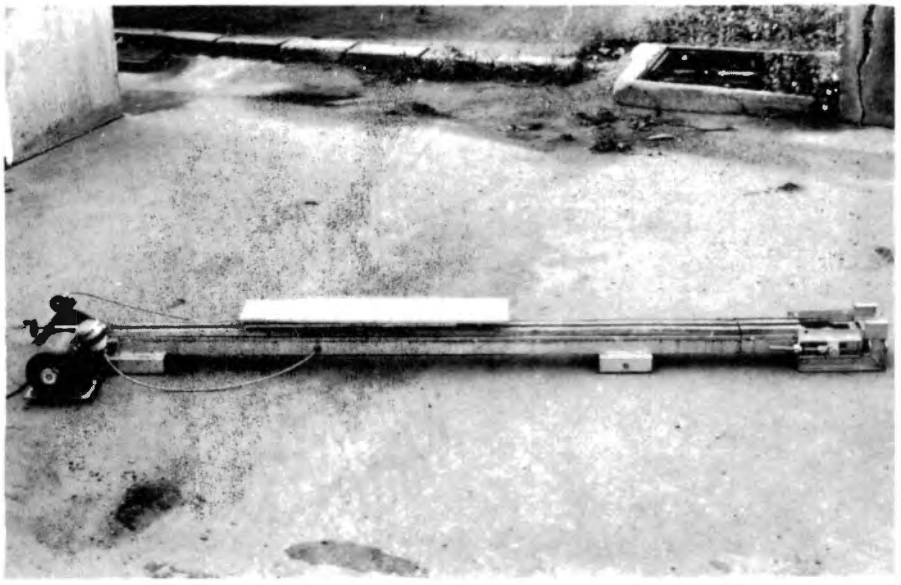

Figure 6. Track Device Used in Spray Application

Effect of Changing Crack Depths and Crack Widths Using Four Depths and Four Crack Widths

The statistical design for this test was a 3 X 4 X 4 X 4 factorial arrangement of treatments in a randomized block design with each level of the factors being analyzed separately. There were four replicates with the treatment order randomized separately for each replicate. Analysis of variance tables containing mean squares and probability of higher F values for three test surfaces are in the appendix.

A Spraying Systems Multi-Teejet^{R} fan nozzle, orifice #800067 (fine fan jet), was used during this study. The tank concentration was .08% chlordane with benzene as a carrier. The tank pressure was .7 kg per square cm with an application speed of .4 m per second. This pressure-speed combination was considered optimum for maximum deposit and lack of drift.

The crack depths used were 5, 10, 15, and 20 mm. The crack widths were 3, 6, 9, and 12 mm giving a total of sixteen treatments.

The surface-A plates were placed at the four sample areas. Each plate was held in place by double-sided carpet tape. The surface-B plates were perpendicular to the surface and held in place with carpet tape (Fig. 7).

Tests were conducted using a randomized order of treatments. For any depth, surface-A and surface-B plates were secured at each sample area and the width was then set. Crack width was measured between the surface-B plates at locations one and four.

The track device and the artificial crack were parallel so that the nozzle assembly would travel the length of the crack passing over the center of the crack from location one through location four. The track

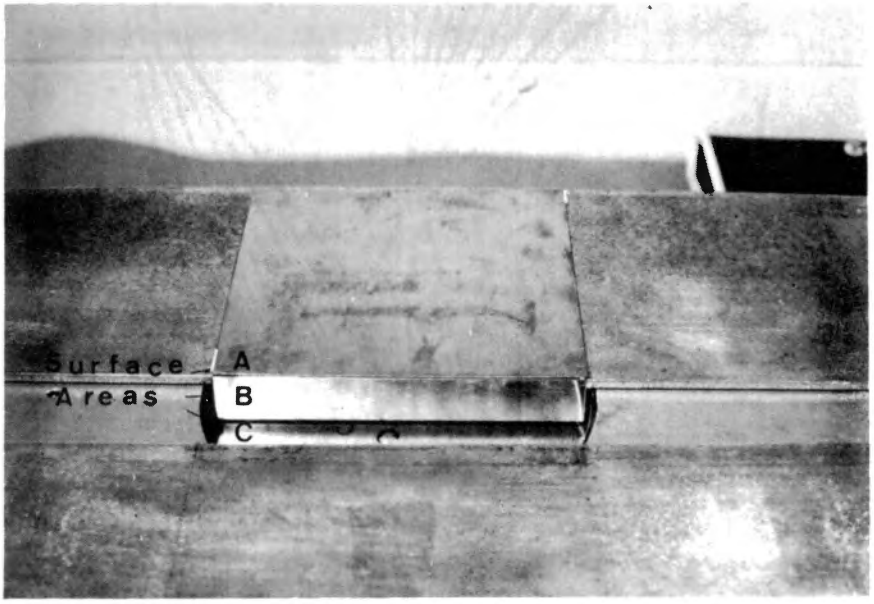

Figure 7. Sample Area with Sample Plates in Position

device was approximately 1.83 meters long. This length allowed a 30.48 cm run from the time the track started moving until the first sample area was sprayed. There were 30.48 cm from the fourth sample area until the end of the track run. This extra distance on each end allowed the track to reach the desired speed before the sample areas were reached by the spray nozzle. In addition this prevented a build up of chemical at the fourth location since the nozzle assembly was past the end of the crack when the run was completed.

When the crack width and depth were set, the angle and distance checked, the spray system was activated. The tank pressure was set, and the chemical was allowed to flow into a container until all air bubbles were out of the liquid hose.

The nozzle assembly was allowed to make one pass over the sample areas. At the end of the track the spray system was turned off. After the chemical was applied it was allowed to evaporate until the surface was dry. The sample plates and petri dishes were then removed from the test apparatus and taken from the test area to a laboratory where the chemical was removed.

The sample plates were then washed with benzene to remove the chemical residue. Recovery test indicated that washing was sufficient to remove all the chemical residue. Dilutions were at a rate, indicated in pre-test, that would produce solutions of an optimun concentration for analysis. The surface-A plates were washed then diluted to 40 ml of solution. The surface-B plates and petri dishes were washed then diluted to 10 ml each. All results were corrected for dilution. The samples containing the chemical residues were then stored in stoppered test tubes 20 degrees C until they were analyzed. All sixteen

treatments were run in one day. No chromatographic clean-up was necessary since carrier and solvent used were the same, and no other source of contamination was present.

During one randomly selected treatment in each replicate, eight magnesium oxide-coated slides were placed on the treatment surface. Two slides were placed between each sample area to record the droplet activity and determine droplet sizes. After treatment the slides were coded as to location, whether distal or proximal to the track device, and to what treatment was used. Slides were then stored in a slide box until all tests were completed. They were then photographed, and the effects of different treatments in different replicates on droplet activity were compared.

For analysis, all samples from each location were run as a unit each day for the next four days. All samples for location one were run one day, all samples for location two were run the next day, and so on. This was done for two reasons: (1) only a relatively small number of samples could be run each day due to the long retention time of chlordane, and (2) by this method the location effect would also be the same as the day effect for statistical analysis. This in effect combined two sources of variation into one.

CHAPTER IV

RESULTS AND DISCUSSION

Effect of Changing Depths and Crack Widths Using Four Depths and Four Crack Widths

The amount of insecticide deposited on test surfaces and magnesium oxide-coated slides using various crack widths and depths was determined using chromatographic analysis.

Outer Surface of Crack - Surface A

Analysis of variance of the data for Surface A showed that there was no significant effect due to depth, width, or interaction between these two factors. This indicates that as the depth and the width increase there will not be an increase in the amount of insecticide deposited. Observing Table I, it can be seen that the above statements are accurate. The amount of insecticide deposited on Surface A ranges from 238.253 mg to 261.335 mg with a mean deposit of 250.70 mg. Another way to view the data is presented in Figure 8. Here it can be seen that neither width nor depth has an effect on the amount of deposit. Generally it can be said that the amount of insecticide deposited on the outside of a crack will remain relatively constant at all widths and depths used in this test.

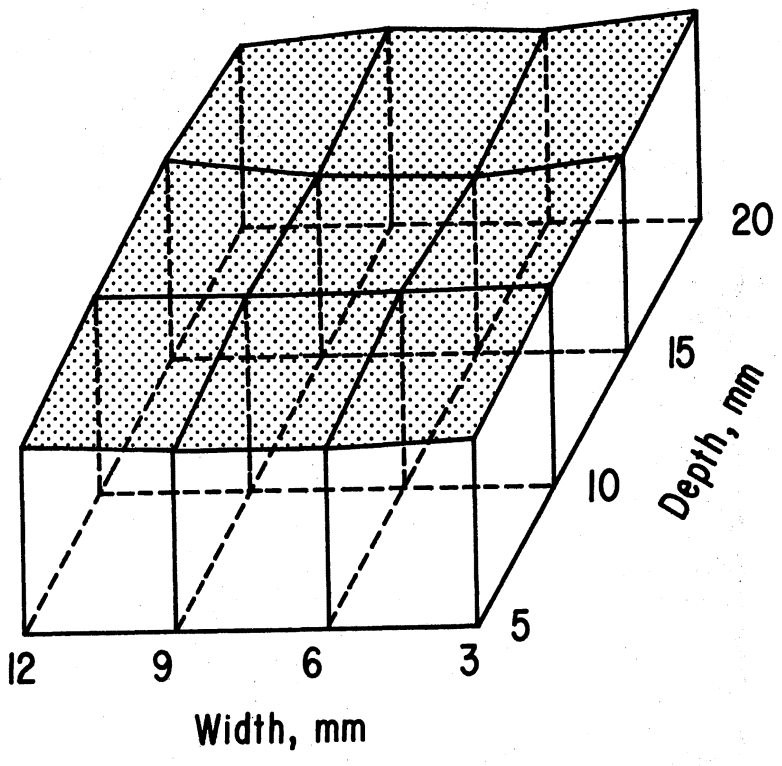

Figure 8. Three Dimensional Surface Derived from Table I for Test Surface A Depicting Amount of Insecticide Deposited at Various Crack Depths and Widths

Crack Walls - Surface B

Analysis of variance for Surface B indicated that there was a highly significant depth effect. It can be seen (Fig. 9) that as the depth increases, the amount of insecticide deposited also increases.

The width effect is also shown to be significant. The amount of insecticide deposited also increases as the width increases up to 12 mm, at which point there is a decrease in the amount of deposit. It will be noted that at the lower depths, 5 mm and 10 mm, there is a reduction in the amount of deposit as the crack width is changed from 3 mm to 6 mm. This implies that where the surface area of the crack depth is small, there will be less insecticide deposited. This belief is further strengthened by the fact that at the 6 mm width and 15 mm and 20 mm depths, there is a sharp increase in the amount of insecticide deposited. It can be said that as crack width and depth increased, the amount of insecticide deposited increased until a point where the crack is so wide that some insecticide is apparently lost, as at the 12 mm width in the study. It is likely that at this width the air turbulence is such that some insecticide is blown out of the crack or into the void beyond the crack walls. Figure 10 shows that there is a marked increase in the amount of insecticide deposited at 12 mm on Surface C.

Analysis of variance showed that the width by crack interaction is also significant. This indicates that as the crack gets wider and deeper, the amount of insecticide deposited increases. The overall mean for Surface B was 3.178 mg of insecticide.

Inner Surface of Crack - Surface C

Analysis of variance showed that depth, width, and depth by width

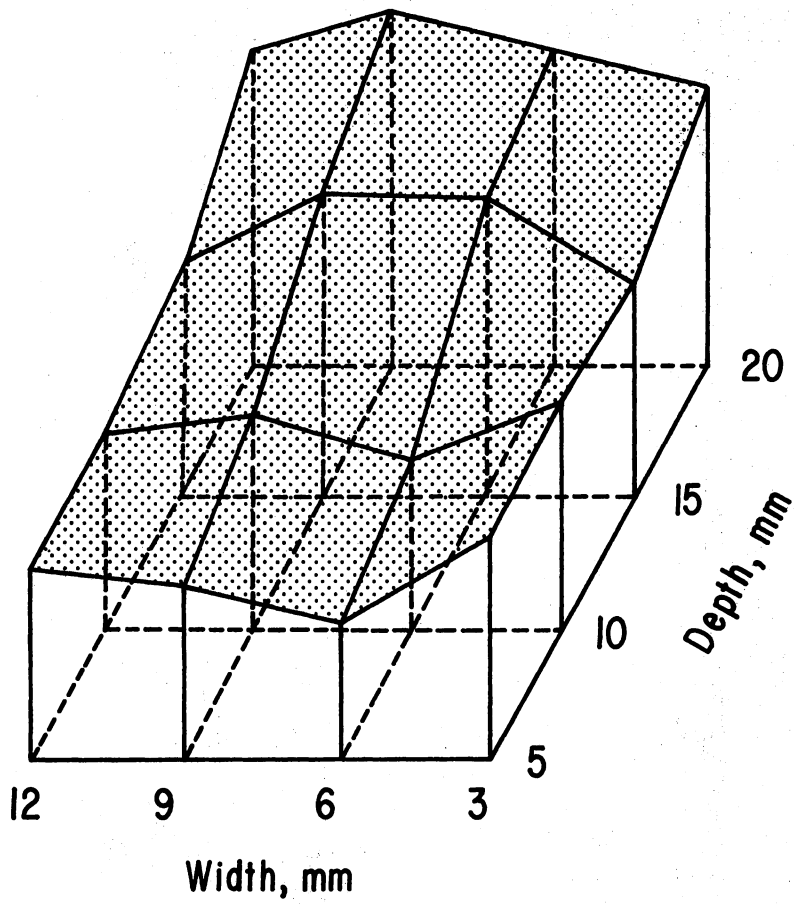

Figure 9. Three Dimensional Surface Derived from Table I for Test Surface B Depicting Amount of Insecticide Deposited at Various Crack Depths and Widths

interaction was highly significant. It can be seen (Fig. 10) that as width increases, the amount of insecticide deposited increases. It can also be observed that while the depth effect is significant, it has a smaller effect on the amount of deposit. It appears that the amount of material deposited on Surface C is affected by each depth only when crack is more than 15 mm deep and only when it is more than 6 mm wide.

Magnesium Oxide Slide Study

Efforts to study droplet sizes proved to be useless because of the high degree of overlapping and the erratic behavior of the droplets. It is believed that this was due to the low tank pressure and the nearness of the slides to the sprayer nozzle. It has been shown that low spraying pressures produced large droplets and that as pressure is increased droplets are smaller and sizes are more uniform (Shepard, 1951). Photographs (Fig. 11) showed that there was coagulation of droplets causing large surface eruptions on the slide. It is also seen that the droplets appeared to be traveling at such a high rate of speed that they would hit the surface of the slide, penetrate the magnesium oxide layer, and travel for some distance under this layer. There was no apparent pattern in the direction from which the droplets were hitting the slide. Observation of the slide indicated that droplets failed to impinge on initial contact and proceeded to bounce around. While the application was made in one direction, the direction of deposit varied.

Results indicate that this method of droplet study is unsatisfactory for this test apparatus due to the erratic size and action of the droplets. However it does give a picture of what the droplets are doing at Surface A of this test apparatus.

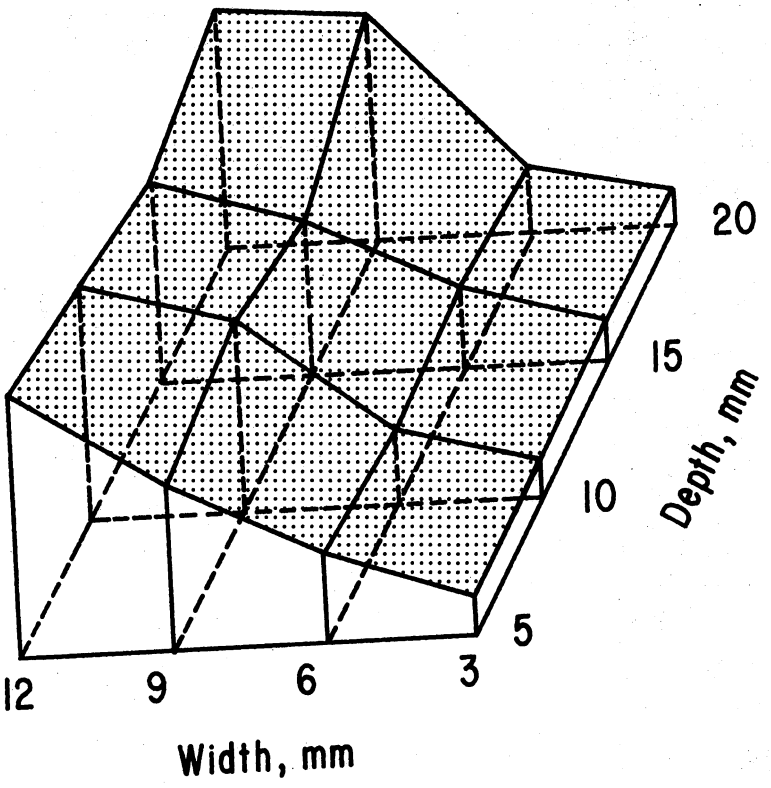

Figure 10. Three Dimensional Surface Derived from Table I for Test Surface C Depicting Amount of Insecticide Deposited at Various Crack Depths and Widths

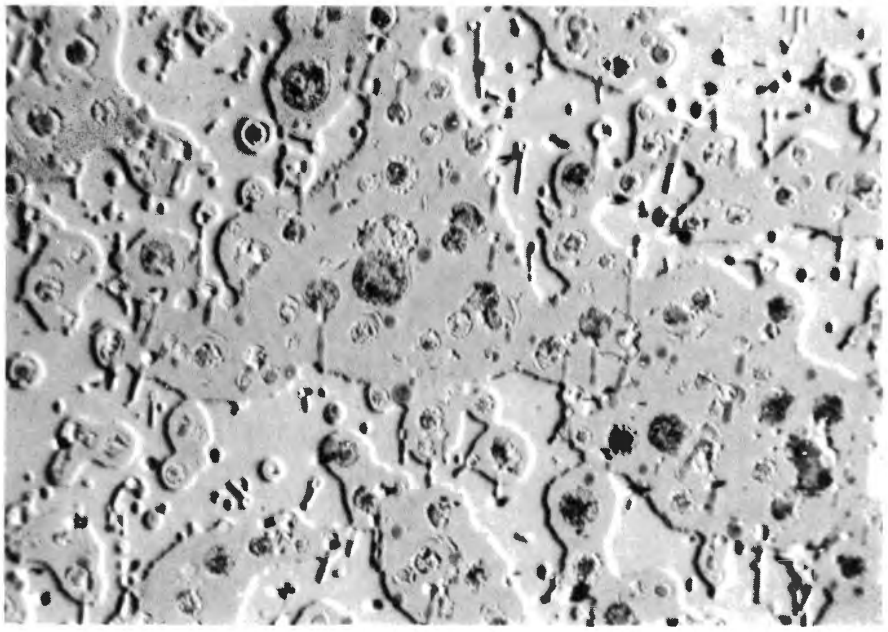

Figure 11. Typical Pattern Produced by Spray Droplets Showing Eruptions, Craters, and Tunnels

CHAPTER V

SUMMARY AND CONCLUSIONS

Effect of Changing Depths and Crack Widths Using Four Depths and Four Crack Widths

A crack's width and depth have very little effect on the amount of insecticide deposited on the outside of the crack. Factors such as rate of application, concentration of insecticide, and tank pressure would have a more direct effect on the amount of deposit. The effect of air turbulence, as shown in magnesium oxide slide study, is an important factor. While other factors such as humidity and temperature were not considered in this study, other researchers have shown their importance in spray deposition.

The amount of insecticide deposited along the interior of a crack is strongly influenced by the width of the crack. The wider the crack opening, the more insecticide deposited.

Data collected using the test apparatus has shown that the apparatus is able to provide a great deal of information about the factors influencing the amount of insecticide deposited in crack and crevice treatment. The apparatus and techniques utilized during this study have proved to be accurate and sensitive to changes in crack widths and depths. This system also gives valuable information as to the

efficiency of the application equipment that was used in this study. The next step is to test the apparatus using pressures, concentrations, and methods (injection) presently being used in pest control operations.

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TABLE I

THE TOTAL MEANS OF THE AMOUNT OF CHLORDANE IN MILLIGRAMS DEPOSITED ON THREE TEST SURFACES

Depth[1]	Width[1]	Surface		
		A	B	C
5	3	248.385	3.016	2.899
5	6	239.804	1.862	6.193
5	9	248.555	2.283	11.043
5	12	248.080	2.540	16.574
10	3	255.545	3.041	2.631
10	6	251.673	2.233	5.269
10	9	261.335	3.342	13.101
10	12	255.209	2.479	15.824
15	3	255.761	2.870	2.887
15	6	244.890	3.999	5.730
15	9	254.817	3.917	10.468
15	12	255.423	3.054	13.770
20	3	256.048	3.660	2.198
20	6	246.666	4.171	4.646
20	9	250.868	4.627	14.727
20	12	238.253	3.753	15.848

[1]Measured in millimeters.

TABLE II

ANALYSIS OF VARIANCE FOR THE AMOUNT OF CHLORDANE DEPOSITED ON SURFACE A AT ALL COMBINATIONS OF CRACK WIDTHS AND DEPTHS

Source of variation	df	SS	MS	F value	Prob F
Corrected Total	255	218431.683	856.595		
Rep. (R)	3	16689.323	5563.108		
Depth (D)	3	3793.163	1264.388	1.576	0.195
Width (W)	3	3021.420	1007.140	1.255	0.290
D X W	9	2655.297	295.033	0.368	0.949
Location (L)	3	7271.568	2423.856	3.021	0.030
L X D	9	3386.032	376.226	0.469	0.894
L X W	9	5380.480	597.831	0.745	0.669
L X D X W	27	24577.170	910.266	1.134	0.304
R X D	9	3411.774	379.086		
R X W	9	8793.465	977.052		
R X D X W	27	18474.654	684.246		
R X L	9	17997.618	1999.735		
R X L X D	27	15936.347	590.235		
R X L X W	27	25902.830	959.364		
R X L X D L W	81	61140.543	754.822		
R X D W L	189	151657.230	802.419		
Overall Mean			250.707		

TABLE III

ANALYSIS OF VARIANCE FOR THE AMOUNT OF CHLORDANE DEPOSITED ON SURFACE B AT ALL COMBINATIONS OF CRACK WIDTHS AND DEPTHS

Source of Variation	df	SS	MS	F value	Prob F
Corrected Total	255	348.761	1.368		
Rep. (R)	3	12.747	4.249		
Depth (D)	3	100.748	33.583	40.015	0.0001
Width (W)	3	12.507	4.169	4.968	0.003
D X W	9	36.676	4.075	4.856	0.0001
Location (L)	3	2.992	0.997	1.188	0.315
L X D	9	4.578	0.509	0.606	0.792
L X W	9	1.407	0.156	1.186	0.995
L X D X W	27	18.489	0.685	0.816	0.728
R X D	9	10.434	1.159		
R X W	9	15.242	1.694		
R X D X W	27	31.520	1.167		
R X L	9	4.405	0.489		
R X L X D	27	31.236	1.157		
R X L X W	27	18.945	0.702		
R X L X D X W	81	46.835	0.578		
R X D W L	189	158.617	0.839		
Overall Mean			3.178		

TABLE IV

ANALYSIS OF VARIANCE FOR THE AMOUNT OF CHLORDANE DEPOSITED ON SURFACE C AT ALL COMBINATIONS OF CRACK WIDTHS AND DEPTHS

Source of Variation	df	SS	MS	F value	Prob F
Corrected Total	255	7961.286	31.221		
Rep. (R)	3	28.529	9.510		
Depth (D)	3	52.271	17.424	5.104	0.002
Width (D)	3	226.329	2266.000	663.873	0.0001
D X W	9	227.214	25.246	7.395	0.0001
Location (L)	3	39.442	13.147	3.851	0.011
L X D	9	41.207	4.579	1.341	0.218
L X W	9	48.539	5.393	1.580	0.123
L X D X W	27	79.889	2.959	0.867	0.659
R X D	9	14.270	1.586		
R X W	9	50.819	5.647		
R X D X W	27	87.569	3.243		
R X L	9	60.206	6.690		
R X L X D	27	64.616	2.393		
R X L X W	27	69.535	2.575		
R X L X D X W	81	298.194	3.681		
R X D W L	189	645.208	3.414		
Overall Mean			8.988		

VITA

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