A STUDY OF CERTAIN WOOD PRESERVATIVES RELATIVE TO THEIR TOXICITY TO THE HONEYBEE AND THEIR USE IN HIVE PRESERVATION

By

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PREFACE

The beekeeping industry has an expensive annual replacement of beehive equipment from losses due to fungous diseases and insect attack. This loss has greatly increased in the South during the last twenty years due to the exhaustion of the virgin stands of cypress timber which was resistant to wood destroying pests. With the proper application of wood preservatives beehive equipment constructed out of inferior woods can have their life greatly extended. The problem is more than merely wood protection. A good wood preservative acts as an insecticide as well as a fungicide, and for this reason care must be exercised in selecting preservatives for beehive treatment, since the honeybee lives in contact with the hive. The purpose of this study is to evaluate various wood preservatives as to their use in hive preservation.

In 1948 the writer became interested in this beekeeping problem and through the encouragement of Dr. Donald Ashdown, then Associate Professor of Entomology at Oklahoma Agricultural and Mechanical College, investigational work was begun in the fall of that year. This study is threefold; first, to determine the relative toxicity of the various wood preservatives to the honeybee, and the effects of various air drying periods on their toxicity; second, to determine the cost of treating the various beehive parts with the different preservating materials; and third, to develop and evaluate a satisfactory treatment program for the beekeeper through the use of accelerated stake tests.

The writer wishes to express his appreciation to Dr. Donald Ashdown and Dr. F. A. Fenton for their valuable guidance and counsel during these investigations and the writing of this manuscript. The writer is indebted to Drs. R. G. Dahms, D. E. Howell and R. R. Walton for their helpful suggestions and criticisms of the report. The writer is especially indebted to Dr. John T. Creighton of the University of Florida for his encouragement and sympathetic understanding during the period of these investigations.

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INTRODUCTION

Beekeepers are in need of a satisfactory wood preservative for treating beehive equipment. This is especially true in the Southern States. Until recent years beehives in the South were constructed of heart cypress, a wood very resistant to decay and insect attack. Cypress is a very slow growing tree, and once the virgin stands are removed the supply of heart cypress will be exhausted. The sap wood, which makes up the majority of the second growth trees, rots about as fast as second growth pine. The loss of heart cypress as a raw material for beehives has created a problem for most Southern beekeepers.

Beehives remain in the open the year around. Not only are they subjected to wetting by the elements, but during the winter months considerable moisture forms in the hives. The moisture hastens the rotting of the hives, particularly at the joints.

In many parts of the Southern States, beekeeping is a migratory business. In order to obtain maximum yields from his colonies the beekeeper must move his bees three to four times a season to locations which have sufficient nectar producing flowers to make a surplus of honey. In moving hundreds of colonies, many beekeepers do not carry hive stands, because of the extra load. This practice places the bottom boards of the hives in contact with the soil. Wood in contact with soil remains moist and this moist condition is conducive to rots and termite attack.

Economic Importance

The honeybee, Apis mellifera Linne, is an important part of America's agriculture. The production of honey in the United States during 1951 was 259,006,000 pounds with a value of over $50,000,000.[1] In addition to the production of honey, the honeybee aids the American economy with wax production exceeding 4,700,000 pounds annually with a value of over $2,100,000. In addition to the cash returns the beekeeper receives for the honey and wax produced, the honeybee is many times more valuable as a pollinator of crops. Grout[2] estimates the value of the honeybee as a pollinator of agricultural crops in the United States to exceed twenty times its value as a producer of honey and wax. This billion dollar benefit of plant pollination is mostly contributed free to the American farmer by the beekeeper. However, in limited sections of the country, the fruit grower, vegetable grower, and legume seed producer realize the importance of the honeybee in the pollination of their crops for maximum yield and they have entered into agreements with beekeepers for this service.

The problems of beekeeping, like other branches of agriculture, are many. The maintaining of good beehives to house the colonies is an annual expense of the beekeeper. In 1951[3] there were 5,581,000 colonies of bees in the United States. The life of a beehive, under average weather and maintenance conditions, is approximately ten years. This

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[1] USDA, Bureau of Agricultural Economics, 1951 Florida Honey Report, Orlando, Florida, 1952.

[2] Roy A. Grout, The Hive and the Honeybee, pp. 223, Illinois, 1946.

[3] USDA, Bureau of Agricultural Economics, Honey Report - July 1951, Orlando, Florida, 1951.

means the beekeepers in the United States have an equipment replacement of 558,100 beehives annually. Each 10-frame Langstroth beehive consisting of a bottom, brood nest, two shallow supers and a cover, contains the following number of board feet: bottom 3.34, brood nest 5.0, two shallow supers 7.0, and cover 3.5. This makes a total of 18.8 board feet in each hive. In terms of the 558,100 beehives lost each year through decay and termite attack, over 10,500,000 board feet of the best grade clear lumber is required to make this replacement. At a conservative figure of 150 dollars a thousand board feet, the loss in lumber alone exceeds 1,500,000 dollars a year. This does not include construction costs or time and money spent in painting and replacing the decayed and destroyed parts. If these items were included the cost would be over two million dollars annually.

Beekeeping is an agricultural pursuit, and for any phase of agriculture to pay a satisfactory return to the operator costs must be considered on every activity and held to a minimum. The replacing of hive parts that become unserviceable must be kept at a low level if the beekeeper is to be successful. Painting beehives is expensive and does not adequately protect them. Today many commercial beekeepers consider the annual painting of their beehives as too expensive an operation. Therefore, much of the beekeeping equipment in the United States is given two or three coats of paint when first installed and used until it is necessary to replace them. Hive replacement is a problem of the beekeeping industry. Proper treatment with a satisfactory wood preservative before painting would greatly reduce this annual expense of the beekeeper.

The objects of this study were to evaluate certain wood preservatives from the standpoint of toxicity to honeybees, resistance to rots and termite attack, and whether they were economical for use in the beekeeping industry. Such information is needed before a general recommendation can be made to commercial beekeepers.

Characteristics of a Good Wood Preservative

Some characteristics of an ideal wood preservative for beehive treatment are listed below. The preservatives studied in these experiments were evaluated according to this list of ideals.

1. Non-toxic to the honeybee.
2. An effective long lasting fungicide preventing wood rot.
3. An effective agent in termite protection.
4. Penetrate wood easily and quickly.
5. Inexpensive.
6. Non-caustic to the operator.
7. Odorless after a short period of airing, so as not to affect the taste of honey.
8. Should not affect the final outside coat of paint.

REVIEW OF THE LITERATURE

The author made a search of the literature at the Library of the Oklahoma Agricultural and Mechanical College and at the Library of the University of Florida. No articles were located dealing specifically with the relative toxicity of the various commercial wood preservatives to the honeybee. Numerous articles, some of which are cited in this report, were found dealing with practical recommendations of wood preservatives as hive treatments. Most of these articles were by practical beekeepers who had tried a given preservative without noticeable effect to his bees. These recommendations were based on very limited observations. Articles of this type, though interesting, were of little or no value to this study.

The literature in the field of wood preservation is voluminous. In the many articles read in this field the writer was unable to find any mention as to what effects the various chemicals would have on the honeybee. A few of the articles in this field were pertinent to this study and are given in the cited literature.

GENERAL OUTLINE OF EXPERIMENTS

This study was divided into three parts. Each part will be discussed separately, with a general discussion appearing at the end of the paper.

Part one deals with a study of the various wood preservatives as contact insecticides to the worker honeybee. Worker honeybees were caged against surfaces of wood which had been treated with various wood preservatives. The effects of various air drying periods between treatment and exposure of the honeybees were evaluated. A series of tests were run to determine if certain of the toxic wood preservatives acted as fumigants as well as contact poisons.

Part two presents the results of a study of the cost of using the various preservatives for hive treatment. The chemicals were evaluated on the basis of the different hive parts.

Part three presents data collected over a period of two and a half years to determine how effective the various wood preservatives were when placed in contact with the soil. In this study the test panels were given a five-minute soak, a treatment which can easily fit into the beekeeper's work program.

TOXICITY TESTS OF SOME WOOD PRESERVATIVES TO THE HONEYBEE

The problem of lengthening the life of exposed wood is two-fold. The wood must be protected from the action of fungous diseases and also protected from wood feeding insects. Since many of the wood preservatives act as an insecticide as well as a fungicide, the effects of such a preservative on the honeybee is a vital question to be answered. The honeybee lives in direct contact with the beehive, therefore, any chemical with insecticidal properties which is applied to the surface of the beehive by a dipping method would come in contact with the bees in the hive. A preserving material highly toxic to the honeybee on contact could be very detrimental to the colony. For this reason a series of contact cage tests were run to evaluate the various wood preservatives studied.

The author recognizes that the behavior responses of bees in small cages differs from those of bees in normal colonies engaged in field activities. In addition to the confinement, the lack of a queen, combs, and colony organization, as well as a change in food affects their behavior. Caged bees are subjected to treatments they would not undergo in their usual environment. Nevertheless cage experiments often give fundamental information that cannot be obtained otherwise.

MATERIALS AND EQUIPMENT

List of Chemicals Tested

No attempt was made to test all wood preservatives available on the present market. Representative samples of water soluble and oil soluble materials were included in these tests. One new preservative, copper 3-phenylsalicylate was included. The materials tested are readily available and are known to have wood preserving properties.

The following are the chemicals used in the toxicity studies:

1. Carbolineum
2. Celcure
3. Chromated zinc chloride
4. Coal-tar creosote
5. Copper 3-phenylsalicylate
6. Copper naphthenate
7. Cuprinol No. 70 - Brown Stain
8. Pentachlorophenol
9. Zinc naphthenate

Limited tests and observations were made on the following materials which are used as protective agents:

1. White paint
2. Kelley's Rot Proofing Compound
3. Sodium pentachlorophenate
4. Asphalt
5. Coal-tar creosote and crankcase oil

List of Solvents Tested

A series of tests were made to determine if certain solvents, which may be used to dilute wood preservatives, would affect the honeybee. The solvents included in these tests were as follows:

1. Mineral spirits
2. Fuel Oil
3. Carbon tetrachloride
4. Acetone
5. Turpentine
6. White gasoline
7. Xylene
8. Isopropyl alcohol
9. Amyl acetate
10. Kerosene

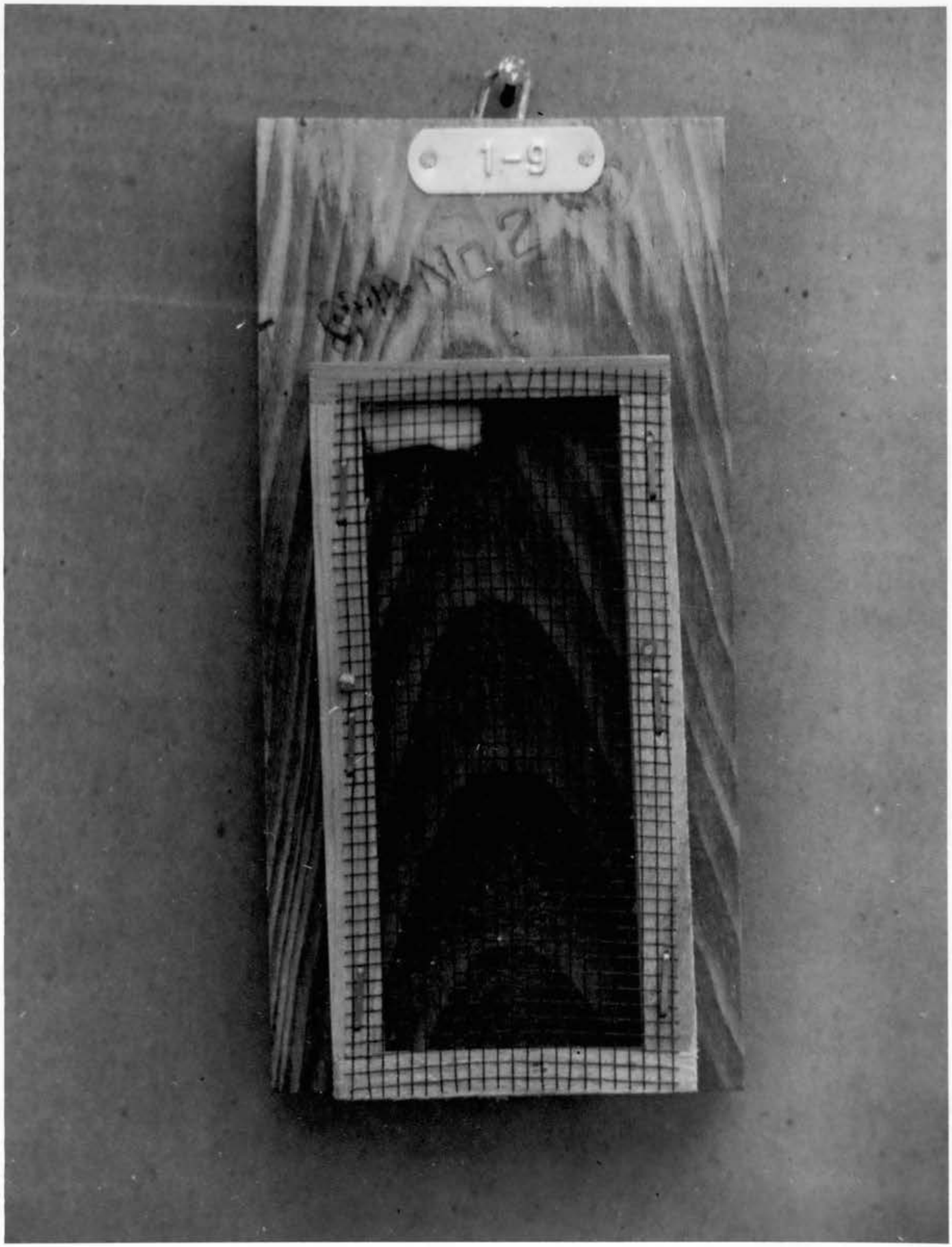
Equipment

Test Panels: One by four, number two grade, pine boards were cut into test panels. Each panel was approximately eight inches long, three and a half inches wide and three-fourth of an inch thick. The test panels were free of knots and resinous areas. A one inch staple was driven in one end of each test panel to facilitate hanging in a shaded location for air drying. A metal number was fastened to each panel at the time of treatment for easy identification (Plate 1).

Test Cages: The test cages were made from pine strips five-eights by three-eights of an inch. Each cage had an inside measurement of two inches wide, five inches long and five-eights of an inch high. The top

Plate 1.

Treated test panel with cage and experiment number attached.


1-9
No.2

of the cage was covered with screen wire. Either a piece of black wire screen with a mesh of eight by eight, or a piece of regular fourteen by eighteen galvanized wire screen was stapled to the cage. The large mesh black wire was more satisfactory than the regular screen wire as the bees were easier to examine during the period they were in the test cages.

At one end of each cage a three-eights inch hole was drilled and fitted with a cork. Test bees were put into the cages through this opening. The test cages were fastened to the treated test panels with two one and one-fourth inch wire nails. The three-eights inch opening was placed at the opposite end from the staple to allow for the easy caging of the test bees.

A special double screened cage was used in the fumigation tests. This cage was the same size as the one described above, but had the top and bottom covered with screen. Between the bottom of the cage and the test panel a one-fourth inch strip was fastened to prevent the test bees from coming in direct contact with the treated surface of the panel.

Test Bees: Italian worker bees were used in all experiments as the test insect. Care was taken to select what was believed to be young bees. Only worker bees which had most of their setae present were used. Older bees usually lose most of the setae on the thorax and abdomen through field activity.

Food for Caged Bees: The worker bees were fed honey candy while in the test cages. This candy was made by adding confectioners' sugar to honey forming a thick paste. The candy was kneaded until all lumps were removed. Sufficient sugar was added until the candy had a consistency of fondant or a putty that would spread well.

Covering for Cages During the Test Period: Three by five cards were used to cover the test cages containing test bees. The cards were used to simulate conditions of the hive by reducing the amount of light in the cage as well as possible air currents.

Containers for Wood Preservatives: Ten pound honey cans, which held five-sixths of a gallon, were used for storing the wood preservatives and for dipping the test panels.

Thermo-humidigraph: A seven day Bristol thermo-humidigraph machine, Model 4069, was used for obtaining temperature and humidity records.

Scales: All wood preservatives requiring dilution and the solvents were weighed on Harvard trip balances with a sensitivity of 0.1 gram and a capacity of two kilograms.

EXPERIMENTAL METHODS

The following methods were used in all the toxicity tests included in this study. The study was conducted over a period of four and a half years. During this period of time several hundred cage tests were conducted in order to obtain satisfactory data for statistical analysis.

Experimental Design

In order to reduce experimental error to a minimum each of the ten series of experiments covered in this section of the report were set up independently of each other and each series was run as a separate unit. Each series contained three replications of each wood preservative in the test and three checks. In Series I, II, and III there were three replications of each wood preservative tested and three checks for each of the three air drying periods. Each of these series contained ninety test panels. The number of wood preservatives tested were limited to nine because of the difficulty of establishing and observing a greater number than ninety test panels in any one series of experiment.

Each series was randomized by placing a card containing the name and the replication number of each chemical and the check in a jar. The cards were withdrawn one at a time and the location of each test panel was assigned for the exposure period. In this manner the location of each preservative in relation to each other was left to chance.

The design used was selected because it allowed for statistical analysis.

Method of Treatment

For each series of experiments the test panels were given a number and the numbers were assigned to the various wood preservatives as mentioned above. At the time of treatment, the cans of wood preservatives were placed on a long work bench and the test panels were placed in front of each can according to the experimental design. Before treatment the numbers were checked with a record sheet made for each wood preservative to make certain that there were no errors. Three test panels were dipped at a time. The dipping in the wood preservative was for five minutes. The panels were agitated once every minute in order that all parts of the panel would be covered with the preservative, and no panels could stick together preventing uniform coverage and penetration. After the five minute soak, the panels were allowed to drain over the can of preservative for a few seconds and then hung in an open tin covered building to air dry until the time of exposure to the test bees.

Method of Air Drying the Test Panels

One of the objects in this research was to determine what effect air drying of wood treated with the preservatives would have on its toxicity to the honeybee. Four time intervals were used in these tests. They were one day after treatment, seven days after treatment, twenty-eight days after treatment and six months or approximately 180 days after treatment. Rarely would it be necessary for a beekeeper to use treated hive equipment on the bees the same day it was treated with the wood preservative. Most repair and hive replacement work is done during the winter months when the bees are inactive and the beekeeper does not manipulate the bees. Hive parts are usually painted before use, therefore one week or longer is available for the air drying of the treated wood before coming in contact with the hive bees.

All test panels were given at least twenty-four hours air drying before bees were caged against the treated surface. In the fumigation tests and the series of solvent tests the bees were caged at the end of the twenty-four hours airing period only. After the five minute soak in the wood preservative the panels were hung in an open tin shed. Each series was separated into groups as to one day after treatment, seven days after treatment and twenty-eight days after treatment. All test panels carried a code number whereby they would be identified at all times as to treatment and time of air drying period. The tin shed protected the panels from rain and direct sunlight. Air circulated freely through the building, which removed any volatile substances such as solvents or preservative materials which sublimed.

Method of Caging Test Bees

After the air drying period the test panels were removed from the hooks near the roof of the shed and test cages were nailed to the treated surface. Care was taken while handling the various panels to prevent the treated surfaces coming in contact with each other. This prevented one chemical from contaminating another. Thirty panels with cages were taken to the apiary at a time and filled with test bees. The test bees in each series were obtained from a single hive. This was done to prevent as far as possible any variation in the test bees. A hive was opened and a frame with bees was placed across the top of the hive. By lightly smoking the bees on the frame they would start engorging with honey. In

Plate 2.

Dipping test panels in the different wood preservatives for a five minute soak.

Plate 3.

Parts of a series of test panels air drying
before use in contact toxicity tests.

this position, with their heads in a cell of honey, the worker bees could be quickly examined for pubescence and easily picked up by their wings. A bee properly held by her four wings was unable to sting and when held in this manner it was easy to start the bee head first through the three-eighths inch opening in the test cage (Plate 4). Ten bees were put in each of the test cages. The inside of the test cage, measuring two by five inches, covered ten square inches of the treated surface. A cage of this size allowed one square inch of treated surface to each of the ten bees caged. An area of this size for each bee was standard in all of the toxicity tests. Bees which were injured, or thought to be injured in the handling process, or which were able to insert their stinger, were removed from the cage. This was done by completely removing the cage, allowing the bees to fly out. The cage was then replaced and ten new bees added. Variations in bees may have affected the uniformity of the results of the experiments, but no differences directly attributable to this factor were observed. As each group of thirty cages were filled with test bees they were taken into the building and arranged according to the randomized plan. A three by five inch index card was placed over each cage. The other panels in the test series were then filled with worker bees in the same manner as described.

Method of Feeding Caged Bees

As soon as all cages in the test series were filled with bees they were fed with honey-candy. Three methods were used in feeding the honey-candy. The first method consisted of filling small containers with honey-candy which were fastened to an inside corner of the test cage before it was nailed to the test panel. The containers were made out of

Plate 4.

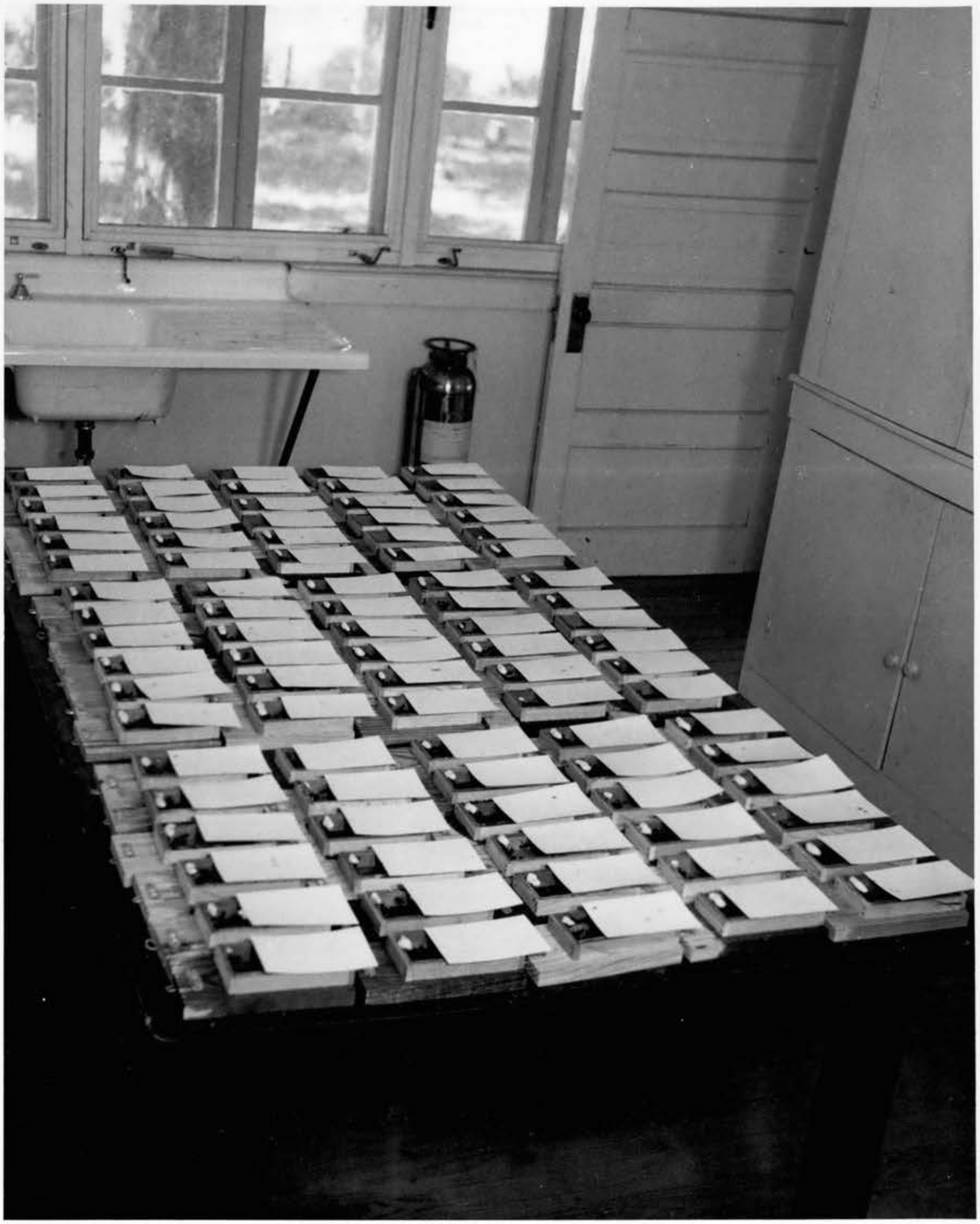
Caging test bees by picking them up by their wings and heading them into the cage.

heavy aluminum foil and measured one-half by one-half by one inch. This method was unsatisfactory because it was impossible to refill the container during the test period. A second method used consisted of making a small roll of the honey-candy by rolling the fondant-like candy until it was one-fourth inch in diameter and then cutting it into pieces one inch long. The pieces of candy were placed on top of the screen wire at one end of the cage. The bees fed on the candy by extending their mouthparts through the holes in the wire screen. This method was satisfactory during dry weather. During rainy and damp weather, the sugar candy absorbed sufficient moisture from the air to cause it to melt and run into the cage. The third method of feeding was a combination of the two already mentioned in that the honey-candy was placed in small containers which were placed on top of the wire screen of the cage. Plastic stoppers from Kimbal vials with an opening of 15 mm. were used to hold the honey-candy. These stoppers had a hollow area one-half inch in diameter which was filled with the honey-candy. With this container only one side of the candy was exposed to the air, and this side was continually fed upon by the bees. The candy did not absorb moisture from the air and soften to the point it would run into the cage. At the time the cages were examined for mortality counts, the small plastic tops were removed and refilled with the soft honey-candy.

During dry weather water was given the caged bees with an eye dropper. Two or three drops of water were placed on the screen wire where it could be taken by the bees. During the seven day test periods water was never given over two or three times.

Plate 5.

A series of cages during the seven-day exposure period.



Method of Examining the Test Cages

The test cages were examined at twenty-four hour intervals during the seven-day exposure period. In preliminary tests, in which satisfactory methods were developed, cages were examined for five, seven, ten, and fourteen days. It was decided after these preliminary tests that a toxic material would have killing effect on the test bees within seven days; therefore the examination period was standardized at seven days.

The test panels were examined by removing the three by five card and counting the number of dead and living bees. The number of dead bees was recorded on the data sheets. The plastic containers were checked for honey-candy, and were refilled where needed. After the examination the card was replaced. At the end of seven days the cages were emptied and discarded.

OUTLINE OF EXPERIMENTS BY SERIES

The ten series of experiments conducted to determine the relative toxicity of certain wood preservatives are given in outline form so that treatment dates, experimental numbers, air drying periods and observation dates will be recorded in this paper.

Series I: Series one contained nine wood preservatives. Ninety test panels were used in this series. Test numbers one, two, and three, each containing thirty test panels, were assigned to this series. Three air drying periods were included. They were one day air drying (test number one), seven days air drying (test number two), and twenty-eight days air drying (test number three.) The test panels were treated May 12, May 6, and April 15, 1950, respectively. Each test contained all nine chemicals replicated three times and three checks. The test bees were caged on May 13, 1950, and were observed for the period of May 14 to 20, 1950.

Series II: This series was a duplication of Series I. Test numbers were assigned as follows: One day airing, test number four; seven days airing, test number five; and twenty-eight days airing, test number six. The test panels were treated October 12, October 6, and September 15, 1950, respectively. The test bees were caged October 13, 1950, and the cages were observed during the period October 14 to 20, 1950.

Series III: This series was also a duplication of Series I and II. Test numbers were assigned as follows: One day airing, test number nine; seven days airing, test number eight; and twenty-eight days airing, test number seven. The test panels were treated April 25, April 19, and

March 29, 1952, respectively. The test bees were caged April 26, 1952, and the cages were observed during the period April 27 to May 3, 1952.

Series IV: This series contained thirty test panels which were air dried for a period of six months. All nine chemicals were included in this test. Each chemical was replicated three times and there were three checks. The test number for this series was number ten. The panels were treated on March 29, 1952, and the test bees caged on September 29, 1952. The cages were observed during the period of September 30 to October 6, 1952.

Series V: This series was a duplication of Series IV. The test number assigned was number eleven. The test panels were treated on April 19, 1952, and test bees caged on October 22, 1952. The cages were observed during the period of October 23 to 29, 1952.

Series VI: This series was a replication of Series IV and V. The test number was twelve. The test panels were treated on April 25, 1952, and test bees were caged on October 25, 1952. The cages were observed during the period of October 26 to November 1, 1952.

Series VII: This series was set up to determine if the wood preservatives which had shown toxicity to the test bees in the contact cage tests caused death by fumigation. Four wood preservatives, replicated three times and three checks were included in this series. The wood preservatives were carbolineum, coal-tar creosote, copper 3-phenylsalicylate and pentachlorophenol. The test panels were treated October 11, 1952, and the test bees were caged on October 12, 1952. Observations were made for five days, during the period of October 13 to 17, 1952. Special double screened cages were used in this test.

Series VIII: Ten solvents and a check were included in this series. Each solvent and the check were replicated three times. On November 8, 1952, the test panels were treated, and test bees were caged on November 9, 1952. The cages were observed during the period of November 10 to 16, 1952.

Series IX: This series was a duplication of Series VII. The test panels were treated on November 14, 1952, and test bees were caged 24 hours later. The cages were observed during the period of November 15 to 19, 1952.

Series X: This series included tests of various preservatives which were observed over a limited period of time. In this series the following materials were tested: white paint, Kelley's Rot Proofing Compound, sodium pentachlorophenate, asphalt and a mixture of coal-tar creosote and crankcase oil. These tests were performed in the fall of 1948.

WOOD PRESERVATIVES TESTED

In the toxicity experiments nine wood preservatives were thoroughly tested with sufficient replications to determine what effect they had on honeybees caged against a treated surface. These wood preservatives will be discussed separately and compared with the check. A discussion as to their relative toxicity to each other will be found at the end of the individual discussions.

Carbolineum

The name carbolineum was first applied to anthracene oils by Avenarius in Germany about 1875. Avenarius recommended the use of chlorinated anthracene oil as a wood preservative which was sold under the trade name of "Avenarius Carbolineum." The product used in these tests was Avenarius Carbolineum, manufactured by the Carbolineum Wood Preserving Company of Milwaukee, Wisconsin. In the United States the name carbolineum is applied to certain of the heavy coal-tar oils, especially to anthracene oil.

Physical properties: Carbolineum is a coal-tar fraction coming off between 270-400 degrees centigrade. The specific gravity is higher than coal-tar creosote. It is a dark brown liquid, which stains wood a deep brown to nearly black. It has a very disagreeable odor, which disappears with time. "Avenarius carbolineum" penetrates wood rapidly. The manufacturer claims it to contain 90 per cent permanent oils and 10 per cent volatile oils or waste products. This is considerably higher than creosote oils which contain approximately 30 per cent permanent oils and 70 per cent volatile oils. Carbolineum has been recommended and used for over 75 years as an effective wood preservative for termite and rot control.

Dilution and Treatment: In these experiments the test panels were given a five minute soak in the commercial product with no dilution. The material is messy to handle, difficult to wash from the hands with soap and water, but easily removed with mineral spirits. The test panels were stained a very dark brown, to nearly black in color. At the end of twenty-four hours air drying the preservative had not completely penetrated the wood, and the panels looked sticky. The carbolineum would easily rub off on your hands when the panels were handled. Considerable odor could be noticed when handling the treated panels.

Tests: Carbolineum was included in all of the toxicity studies. Forty-two panels were treated with this preservative. Nine test panels were included in each of the four air drying periods. Six panels were included in the fumigation studies.

Observations and Results: Test bees caged against panels treated with carbolineum were very excited. They ran over the treated surface and the wire screen of the cage. They continually fanned their wings during the first few hours of exposure to the treated surface. The test bees consumed very little of the honey-candy given them as food during the seven-day observation period.

The results of these tests are given in Table 1. Death occurred faster on these panels than any of the other chemicals tested. On the test panels given twenty-four hours airing forty per cent of the test bees were dead at the end of the first twenty-four hours, and all were dead or dying at the end of forty-eight hours. At the end of three days all of the test bees were dead. On the panels given seven days airing, there was a great reduction in mortality during the first three days; however, 84.4 per cent were dead at the end of the seven-day exposure period. Twenty-eight days airing also reduced the mortality rate with zero mortality during the first forty-eight hours and only 38.8 per cent dead at the end of the seven-day observation period. There was little or no difference between the twenty-eight day panels and the one hundred and eighty day panels. When compared with the checks on untreated panels, carbolineum caused twice the mortality rate as the checks, even after 180 days airing. Figure 1 shows a comparison of all panels with different air drying periods with the check by days.

Celcure

"Celcure" is a patented wood preservative. The first United States patent was issued in 1928 to Gilbert Gunn of Scotland. This patent applied to the use of "a slightly acid aqueous solution of a soluble chromate and a soluble copper salt."[1] A second patent covering a dry formulation was taken out in 1936 and since that date "celcure" has been available in both a liquid and a dry form. The product used in these tests was manufactured by the Celcure Wood Preservative Corporation, Jacksonville, Florida.

Physical Properties: "Celcure" is a yellow colored solution of the preserving salts in a water carrier. A typical solution is composed of 5.6 per cent potassium dichromate, 5.6 per cent copper sulphate, 0.25

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[1] G. M. Hunt and G. A. Garratt, Wood Preservation, McGraw-Hill, New York, New York, 1938.

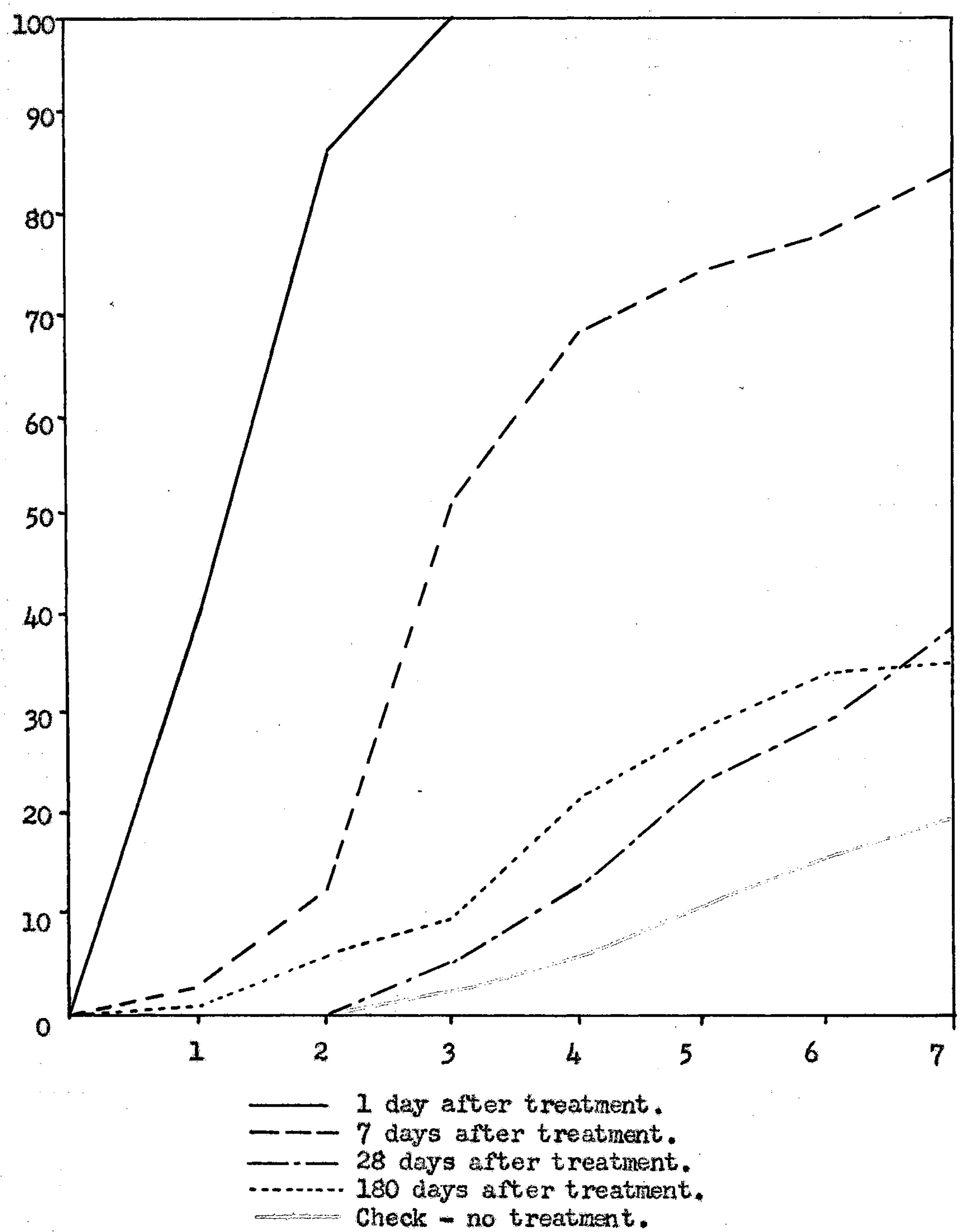
Table 1

Per cent Dead Bees by Days When Caged Against Pine Panels Given a Five Minute Soak in Carbolineum and Air Dried for Different Time Intervals

Test No.	Days Air Dried	Test Series	Per cent Dead Bees in Cages by Days 1	2	3	4	5	6	7
1-1	1	I	60	90	100	-	-	-	-
1-16	1	I	40	100	-	-	-	-	-
1-19	1	I	20	100	-	-	-	-	-
4-1	1	II	80	100	-	-	-	-	-
4-26	1	II	100	-	-	-	-	-	-
4-30	1	II	30	100	-	-	-	-	-
9-30	1	III	10	80	100	-	-	-	-
9-22	1	III	0	60	100	-	-	-	-
9-12	1	III	20	50	100	-	-	-	-
Average of Above in Per cent			40.0	86.6	100	-	-	-	-
2-24	7	I	0	20	80	90	90	90	90
2-7	7	I	30	80	90	100	-	-	-
2-14	7	I	0	0	0	0	0	0	0
5-8	7	II	0	0	30	50	60	60	90
5-29	7	II	0	0	30	30	60	60	80
5-30	7	II	0	0	80	100	-	-	-
8-9	7	III	0	10	60	100	-	-	-
8-4	7	III	0	10	40	80	90	90	100
8-30	7	III	0	0	60	60	70	100	-
Average of Above in Per cent			3.3	13.3	52.2	67.7	74.4	77.7	84.4
3-22	28	I	0	0	0	0	10	10	10
3-15	28	I	0	0	0	0	0	0	0
3-9	28	I	0	0	0	0	10	10	10
6-6	28	II	0	0	0	0	0	20	40
6-15	28	II	0	0	0	30	50	50	70
6-30	28	II	0	0	0	10	40	60	60
7-22	28	III	0	0	10	10	10	10	10
7-21	28	III	0	0	10	30	30	40	70
7-9	28	III	0	0	30	40	60	70	80
Average of Above in Per cent			0	0	5.5	13.3	23.3	30.0	38.8
10-22	180	IV	10	10	20	40	40	40	40
10-21	180	IV	0	30	40	50	70	70	70
10-9	180	IV	0	0	0	30	30	40	50
11-9	180	V	0	0	10	20	30	50	60
11-4	180	V	0	10	10	10	20	20	30
11-30	180	V	0	10	20	30	50	50	50
12-30	180	VI	0	0	0	0	0	20	20
12-22	180	VI	0	0	0	0	0	0	0
12-12	180	VI	0	0	10	10	20	20	30
Average of Above in Per cent			1.1	6.6	10.0	21.1	28.8	34.4	36.6
Checks in Per cent			0	0.3	2.5	6.4	11.7	15.8	19.7

Figure 1.

Mortality Curves in Per cent Dead Bees by Days When Caged Against Test Panels Treated with Carbolineum with Different Air Drying Periods.



per cent acetic acid and 88.5 per cent water. The solution stains wood a light yellow color. It is not objectional to use and does not irritate the skin. Being a water solution of the preserving salts "celcure" has very poor penetration properties when used as dip or brush treatment. However, the licensed distributors recommend this type of treatment for wood preservation. Wood impregnated with "celcure" by the pressure treating method has held up very satisfactorily under field test conditions. The manufacturer claims the solution deposits insoluble toxic compounds to the cell walls of the treated wood. However, the preserving salts have a tendency to leach rapidly out of the wood when placed in a wet place or in contact with the soil.

Dilution and Treatment: Liquid "celcure" was used in tests without dilution. After the soak treatment the panels dried quickly staining the wood a yellow color. There was no odor or objectional feature in handling the preservative.

Tests: "Celcure" was included in all of the toxicity experiments with the exception of the fumigation studies. It was not included in the fumigation studies because of its lack of toxicity to the test bees. Thirty-six panels were treated with this preservative. Nine test panels were included in each of the four air drying periods.

Observation and Results: Table 2 shows the mortality rates of the test bees when caged in contact with "celcure" treated wood. The test bees caged against the panels treated with "celcure" had mortality rates slightly above the checks. There was little or no difference in the mortality rates between the different air drying periods. At the end of the seven-day exposure period, panels given one day air drying and those receiving 180 days air drying had the same mortality rate of 25.5 per cent.

Table 2

Per cent Dead Bees by Days When Caged Against Pine Panels Given a Five Minute Soak in Celcure and Air Dried for Different Time Intervals

Test No.	Days Air Dried	Test Series	Per cent Dead Bees in Cages by Days 1	2	3	4	5	6	7
1-10	1	I	0	0	0	0	0	10	10
1-14	1	I	0	0	0	0	0	0	0
1-28	1	I	0	0	0	0	0	0	0
4-7	1	II	0	0	0	10	30	40	40
4-9	1	II	0	0	0	0	10	30	40
4-17	1	II	0	0	0	10	20	50	60
9-2	1	III	0	0	0	10	10	10	40
9-6	1	III	0	0	10	10	10	20	40
9-4	1	III	0	0	0	0	0	0	0
Average of Above in Per Cent			0	0	1.1	4.4	8.8	17.7	25.5
2-15	7	I	0	0	0	0	0	0	0
2-4	7	I	0	0	0	0	0	0	0
2-5	7	I	0	0	0	0	0	0	0
5-10	7	II	0	0	0	0	20	20	50
5-22	7	II	0	0	0	0	0	0	0
5-25	7	II	0	0	0	0	10	20	30
8-1	7	III	0	0	20	20	20	50	50
8-3	7	III	0	0	10	10	10	10	20
8-15	7	III	0	0	10	20	20	20	30
Average of Above in Per Cent			0	0	4.4	5.5	8.8	13.3	20.0
3-5	28	I	0	0	0	0	0	0	0
3-30	28	I	0	0	0	0	0	0	0
3-8	28	I	0	0	0	0	0	0	10
6-9	28	II	0	0	20	30	60	80	90
6-13	28	II	10	10	10	20	20	20	40
6-28	28	II	0	0	0	0	0	0	0
7-17	28	III	0	0	0	0	10	10	20
7-5	28	III	0	0	0	20	30	40	40
7-3	28	III	0	0	0	10	10	20	30
Average of Above in Per Cent			1.1	1.1	3.3	8.8	14.4	18.8	24.4
10-17	180	IV	10	20	20	40	70	80	90
10-5	180	IV	0	0	0	0	0	10	10
10-3	180	IV	10	10	10	10	10	30	60
11-1	180	V	0	0	0	0	0	0	0
11-3	180	V	0	0	0	10	20	40	40
11-15	180	V	0	0	0	0	0	10	20
12-2	180	VI	0	0	10	10	10	10	10
12-4	180	VI	0	0	0	0	0	0	0
12-6	180	VI	0	0	0	0	0	0	0
Average of Above in Per Cent			2.2	3.3	4.4	7.7	12.2	20.0	25.5
Check (One in each series)			0	0.3	2.5	6.4	11.7	15.8	19.7

This compares favorably with the check which was 19.7 per cent at the end of the seven-day observation period.

From the standpoint of mortality alone, "celcure" would be considered a satisfactory treatment for beehives. However, from the standpoint of wood protection when used under practical treatment methods that can be used by beekeepers, other preservatives were far superior.

Figure 2 shows the mortality of bees caged on "celcure" treated panels in per cent by days for the various air drying periods as compared with the check.

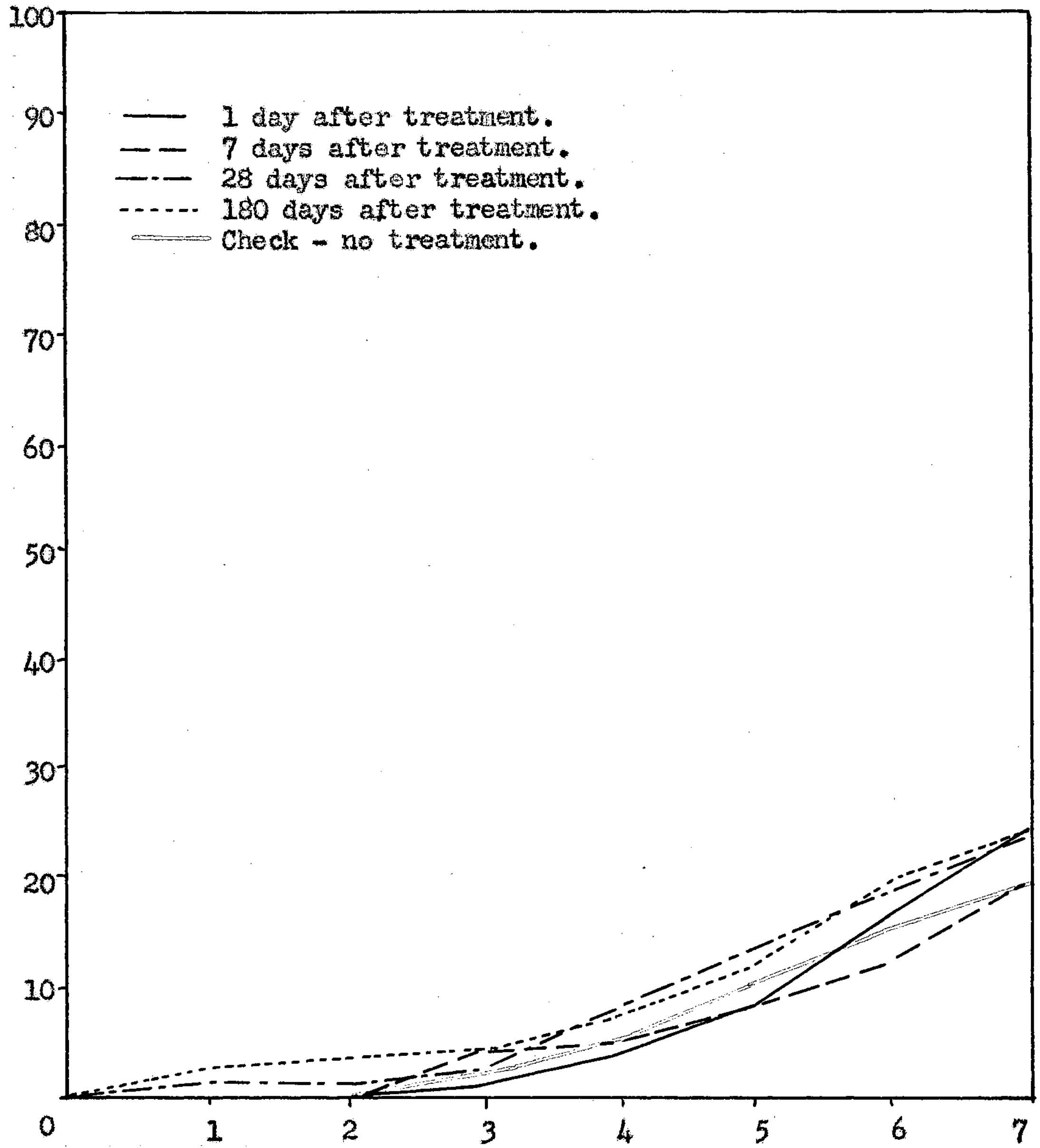
Chromated Zinc Chloride

During the early history of the preservation of wood with chemicals zinc chloride was a standard treatment along with creosote. During 1921 the domestic consumption of zinc chloride was over 51 million pounds. Since that date, however, the use of zinc chloride as a wood preservative has dropped to practically nothing. This drop was due to the leaching characteristics of this chemical along with its caustic action on metals. In 1934 a new formulation of zinc chloride was developed called chromated zinc chloride. This improved wood preserving salt mixture contained zinc chloride and sodium dichromate. The product used in these tests was chromated zinc chloride supplied by the E.I. du Pont de Nemours and Company, Wilmington, Delaware.

Physical Properties: Chromated zinc chloride is an orange colored crystalline powder which readily dissolves in water. The affinity for water is such that the powder must be kept in tight containers, otherwise concentrated solutions will be formed from the moisture in the air. Chromated zinc chloride is a mixture containing 81.5 per cent zinc chloride

Figure 2.

Mortality Curves in Per cent Dead Bees by Days When Caged Against Test Panels Treated with Celcure with Different Periods of Airing.



and 18.5 per cent sodium dichromate.[2] The addition of the sodium dichromate reduces the amount of leaching of regular zinc chloride, and also contributes additional toxicity. It mordants the zinc chloride to the wood-fiber, thus extending the preservative value of the compound. At high retentions chromated zinc chloride adds a high degree of fire resistance to treated wood.

Chromated zinc chloride imparts a light orange color to treated wood. Accelerated field tests have shown it to be a very satisfactory wood preservative when used by the pressure treatment method. Strong solutions of chromated zinc chloride are caustic.

Dilution and Treatment: A ten per cent water solution of chromated zinc chloride was used in these tests. The solution was made by dissolving by weight one part of the preservative in nine parts of water. The salts dissolved quickly forming a light orange liquid. The treated panels air dried rapidly leaving the wood a slight orange color. The tin container in which the solution was kept rusted badly from the caustic action of the chemical. There was no objectional odor or other feature in handling the ten per cent solution.

Tests: Chromated zinc chloride was included in all of the toxicity experiments with the exception of the later fumigation studies. It was not included in the fumigation studies because of its lack of toxicity to the test bees. Thirty-six panels were treated with this preservative. Nine panels were included in each of the four air drying periods.

Observations and Results: The test bees caged against the panels treated with chromated zinc chloride had mortality rates slightly higher

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[2] J. O. Blew, Jr., Developments in Wood Preservatives, Chemical Industries, February, 1949.

than the untreated checks. Table 3 shows these mortality rates. There were some variations in mortality rates in the different series. Series II had the highest mortality rate, beginning with the fifth day. The rapid increase in mortality in this series can be explained by a Florida hurricane occurring on this date and the increase in humidity could have had detrimental effects. It can be seen in Table 3 that at the end of the fourth day the mortality rates on the test panels in this series were below or almost equal to the check.

There was no significant difference between the mortality rates of the chromated zinc chloride panels and those of the check. Figure 3 shows the mortality rates of this preservative in per cent by days for the various air drying periods as compared with the check.

Coal-Tar Creosote

The use of coal-tar creosote was first patented in 1836 by Franz Moll. Creosote may be obtained from other tars than coal, such as wood tar, peat tar, lignite tar, shale tar, oil-gas tar, water-gas tar, and others; each one being somewhat different from the others. The word "creosote" is often used as synonymous with creosote oil. Creosote oil came into common use in the United States during the last half of the 19th Century. During the last fifty years coal-tar solutions have been in common use. The solutions are made by diluting the more expensive creosote oils with less expensive distillates. In addition to the reduction in cost of the creosote oil, the solutions also tend to prevent the checking and weathering of treated wood surfaces. Most creosoting done today is with the diluted creosote oils.

Physical Properties: Coal-tar is distilled into several products

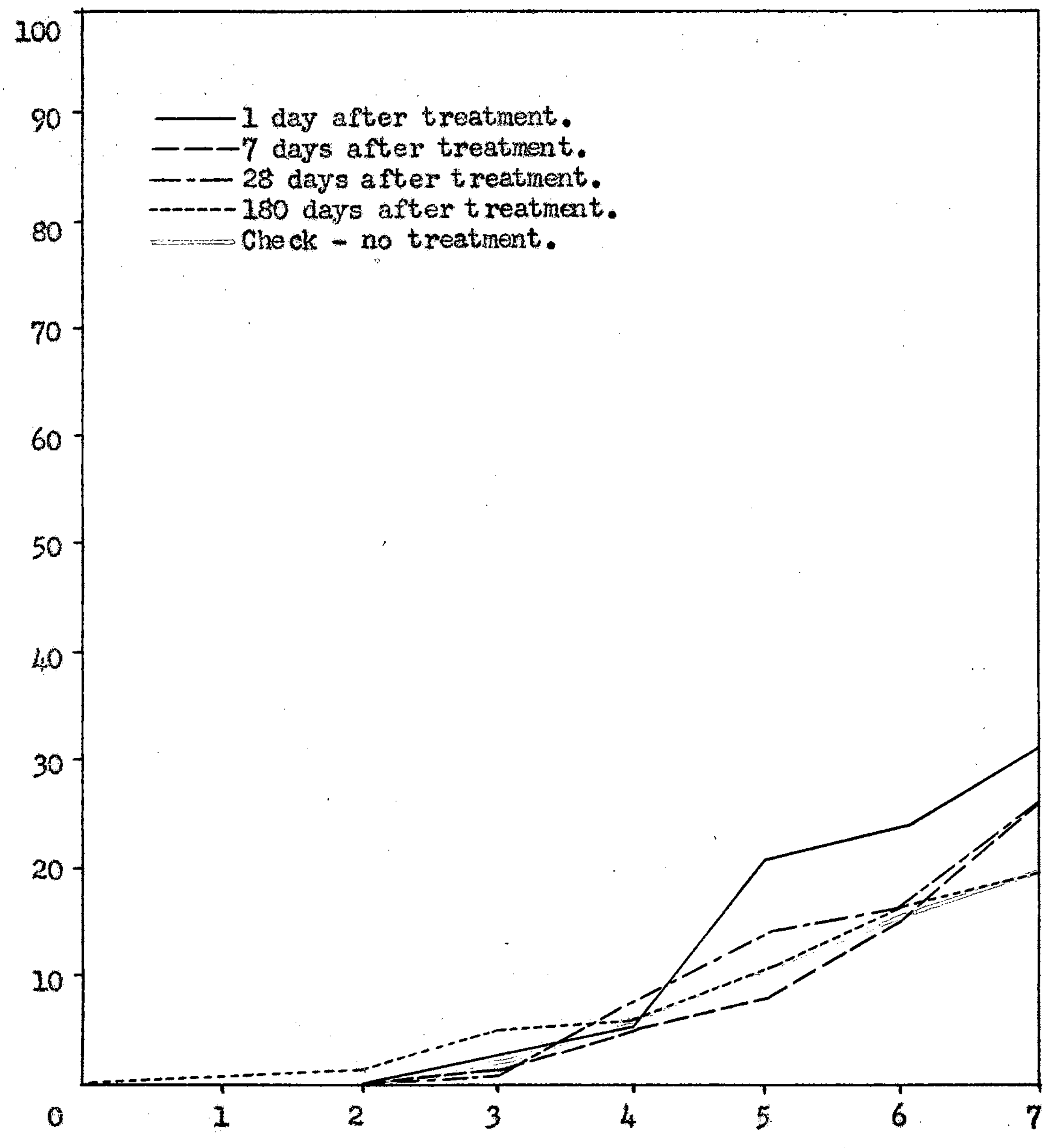
Table 3

Per cent Dead Bees by Days When Caged Against Pine Panels Given a Five Minute Soak in Chromated Zinc Chloride and Air Dried for Different Time Intervals

Test No.	Days Air Dried	Test Series	Per cent Dead Bees in Cages by Days 1	2	3	4	5	6	7
1-5	1	I	0	0	0	0	0	0	0
1-20	1	I	0	0	0	0	0	0	0
1-15	1	I	0	0	0	0	0	0	0
4-8	1	II	0	0	10	10	30	30	30
4-18	1	II	0	0	0	0	70	80	100
4-20	1	II	0	0	10	20	60	70	90
9-28	1	III	0	0	0	10	10	20	20
9-1	1	III	0	0	0	10	10	10	10
9-27	1	III	0	0	0	0	10	10	40
Average of Above in Per cent			0	0	2.2	5.5	21.1	24.4	32.2
2-23	7	I	0	0	0	0	0	0	0
2-20	7	I	0	0	0	0	0	0	10
2-26	7	I	0	0	0	0	0	0	10
5-3	7	II	0	0	0	0	0	20	30
5-12	7	II	0	0	0	10	20	20	40
5-23	7	II	0	0	0	20	30	70	80
8-8	7	III	0	0	0	10	20	20	40
8-7	7	III	0	0	0	0	0	0	20
8-17	7	III	0	0	10	10	10	10	10
Average of Above in Per cent			0	0	1.1	5.5	8.8	15.5	26.6
3-25	28	I	0	0	0	0	0	0	0
3-26	28	I	0	0	0	0	10	10	10
3-10	28	I	0	0	10	10	10	20	20
6-2	28	II	0	0	0	0	10	20	30
6-10	28	II	0	0	0	10	20	20	40
6-22	28	II	0	0	0	30	30	30	60
7-20	28	III	0	0	0	10	10	10	10
7-2	28	III	0	0	0	0	10	10	40
7-29	28	III	0	0	0	10	30	30	30
Average of Above in Per cent			0	0	1.1	7.7	14.4	16.6	26.6
10-20	180	IV	0	0	0	0	0	10	10
10-2	180	IV	0	0	0	0	0	0	0
10-29	180	IV	0	0	0	0	0	0	0
11-8	180	V	10	10	20	20	20	20	40
11-7	180	V	0	10	10	10	50	70	80
11-17	180	V	0	0	20	20	20	20	20
12-28	180	VI	0	0	0	0	0	20	20
12-1	180	VI	0	0	0	10	10	10	10
12-27	180	VI	0	0	0	0	0	0	0
Average of Above in Per cent			1.1	2.2	5.5	6.6	11.1	16.6	20.0
Checks in Per cent			0	0.3	2.5	6.4	11.7	15.8	19.7

Figure 3.

Mortality Curves in Per cent Dead Bees by Days When Caged Against Test Panels Treated with Chromated Zinc Chloride with Different Periods of Airing.



each coming off at different temperatures. Creosote oil distills from the tar between 240-270 degrees centigrade. Rigid specifications for creosote coal-tar solutions have been set by the government and industry regulations. These regulations require the coal-tar product to be at least eighty per cent from a distillate of coal-gas tar or coke-over tar and the remainder twenty per cent filtered or refined coal-gas tar or coke-oven tar. The amount of distillate and other low boiling fractions are limited to not more than 25 per cent. Solutions cannot have more than six per cent coke residue. The specific gravity at 38 degrees centigrade is between 1.05 and 1.12.

Creosote is not a pleasant material to work with. It has a strong odor, bad staining properties, and a blistering effect on many individuals when it comes in contact with the skin. Much of the preserving properties of creosote oil are volatile. This characteristic greatly reduces its effectiveness as a brush or dip treatment. Creosote is objectional also in that treated surfaces cannot be satisfactorily painted. The odor remains for a long time and in closed buildings may be detected for many months. Treated timbers are dark brown or black, and bleed when subjected to high temperatures. For certain types of wood preservation pressure treatment with coal-tar creosote solution is very satisfactory. Rail road cross tires, piling, bridge timbers, etc., fit into this category.

A number of beekeepers have used coal-tar creosote for hive preservation. Madoc[3] in England suggests several weeks airing after treatment before use. This beekeeper found the strong smell of creosoted hives to cause the guard bees to be confused and allow robbing. Hive parts which

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[3]E. W. D. Madoc, Creosote as a Hive Preservative, American Bee Journal, 69-79 February 1929.

had aired six weeks and then used smelled so strong of creosote on a warm day that robbing was a serious factor. Another objection to creosoted hives is the dark color which will not take paint. The dark color absorbs heat rather than reflecting it, thereby causing the combs to melt down on a hot day.

Dilution and Treatment: The coal-tar creosote oil used in these tests was obtained from the Wood Products Laboratory of the University of Florida. It was a commercial grade. For treatment of the test panels the creosote oil was diluted with equal parts of Number 2 fuel oil. The test panels were given the standard five minute dip treatment.

Tests: Coal-tar creosote was included in all of the toxicity studies. Forty-two panels were treated with this preservative. Nine test panels were included in each of the four airing periods. Six panels were included in the fumigation studies.

Observations and Results: The panels treated with coal-tar creosote solution were stained a light brown. They had a decided odor even at the end of the 28-day air drying period. The bees were extremely nervous when first caged against the treated panels. They ran over the surface rapidly, and continued to fan their wings for several hours. They consumed very little of the honey-candy given them as food during the exposure period.

The results of these tests are given in Table 4. Mortality of the test bees was greatest on the panels given one day's airing. Forty-two per cent of these bees were dead at the end of twenty-four hours and ninety-five per cent were dead at the end of five days. There was a gradual reduction in the mortality rates with the increase of the air drying period. At the end of the seven-day observation period, the panels given twenty-eight days airing showed a mortality of forty per cent

Table 4

Per cent Dead Bees by Days When Caged Against Pine Panels Given a Five Minute Soak in Coal Tar Creosote and Air Dried for Different Time Intervals

Test No.	Days Air Dried	Test Series	Per cent Dead Bees in Cages by Days 1	2	3	4	5	6	7
1-13	1	I	10	80	90	100	-	-	-
1-7	1	I	20	60	80	80	80	80	80
1-26	1	I	20	100	-	-	-	-	-
4-14	1	II	100	-	-	-	-	-	-
4-16	1	II	100	-	-	-	-	-	-
4-25	1	II	60	100	-	-	-	-	-
9-16	1	III	0	60	80	90	100	-	-
9-9	1	III	0	0	60	80	80	80	80
9-11	1	III	70	100	-	-	-	-	-
Average of Above in Per cent			42.2	77.7	90.0	94.4	95.5	95.5	95.5
2-11	7	I	0	0	0	0	0	0	0
2-29	7	I	0	0	0	0	0	0	10
2-30	7	I	30	90	90	100	-	-	-
5-6	7	II	100	-	-	-	-	-	-
5-15	7	II	0	20	30	40	60	70	70
5-18	7	II	60	100	-	-	-	-	-
8-26	7	III	10	20	40	60	60	90	100
8-20	7	III	0	0	0	10	40	50	50
8-13	7	III	0	10	10	40	50	50	60
Average of Above in Per cent			22.2	37.7	41.1	50.0	56.6	62.2	65.5
3-7	28	I	0	20	50	50	70	80	90
3-6	28	I	0	0	0	0	0	0	10
3-12	28	I	0	0	0	0	0	0	0
6-4	28	II	0	0	0	0	10	10	10
6-5	28	II	0	10	30	40	60	90	90
6-19	28	II	0	0	10	20	40	50	70
7-24	28	III	0	0	0	0	0	0	0
7-26	28	III	0	0	0	10	40	40	40
7-8	28	III	0	0	0	20	20	40	50
Average of Above in Per cent			0	3.3	10.0	15.5	26.6	34.4	40.0
10-24	180	IV	0	0	0	0	0	0	0
10-26	180	IV	10	40	40	40	40	40	40
10-8	180	IV	0	0	10	20	20	20	20
11-26	180	V	0	0	10	10	40	80	80
11-20	180	V	0	0	10	10	10	30	40
11-13	180	V	0	0	0	10	20	20	30
12-16	180	VI	0	0	0	0	0	0	10
12-9	180	VI	0	0	0	0	0	0	30
12-11	180	VI	0	0	0	0	0	0	10
Average of Above in Per cent			1.1	4.4	7.7	10.0	14.4	21.1	28.8
Checks in Per cent			0	0.3	2.5	6.4	11.7	15.8	19.7

and the panels given one hundred and eighty days airing had only 28.8 per cent. In all series of tests coal-tar creosote showed greater mortality than did the check.

Coal-tar creosote was next to carbolineum, which is a higher fractionate from coal-tar, in test bee mortality. Figure 4 shows the mortality of the coal-tar creosote solution in per cent for the various air drying periods as compared with the check.

Copper 3-phenylsalicylate

Copper 3-phenylsalicylate is a new preservative manufactured by the Dow Chemical Company of Midland, Michigan. This material shows promise as an effective preservative for wood in contact with seeds, plants, fruits and vegetables.[4] Copper 3-phenylsalicylate was developed primarily as a textile preservative for application to materials such as canvas awnings, tarpaulins, shoe liners, shade cloth, fish nets, etc. Field tests indicate this material to be resistant to rots and molds. Tests are in progress to determine its effectiveness as a termite control.

Physical Properties: Copper 3-phenylsalicylate is an odorless, non-volatile, tan crystalline material. It begins to coalesce at 145 degrees centigrade and decomposes at 148-152 degrees centigrade. It is soluble in certain of the organic solvents, such as acetone, amyl acetate, benzene, xylene, etc., to at least five per cent of weight. Tests conducted on 200 human subjects failed to show any skin irritation and produced no skin sensitization.[5] Toxicological tests on laboratory animals

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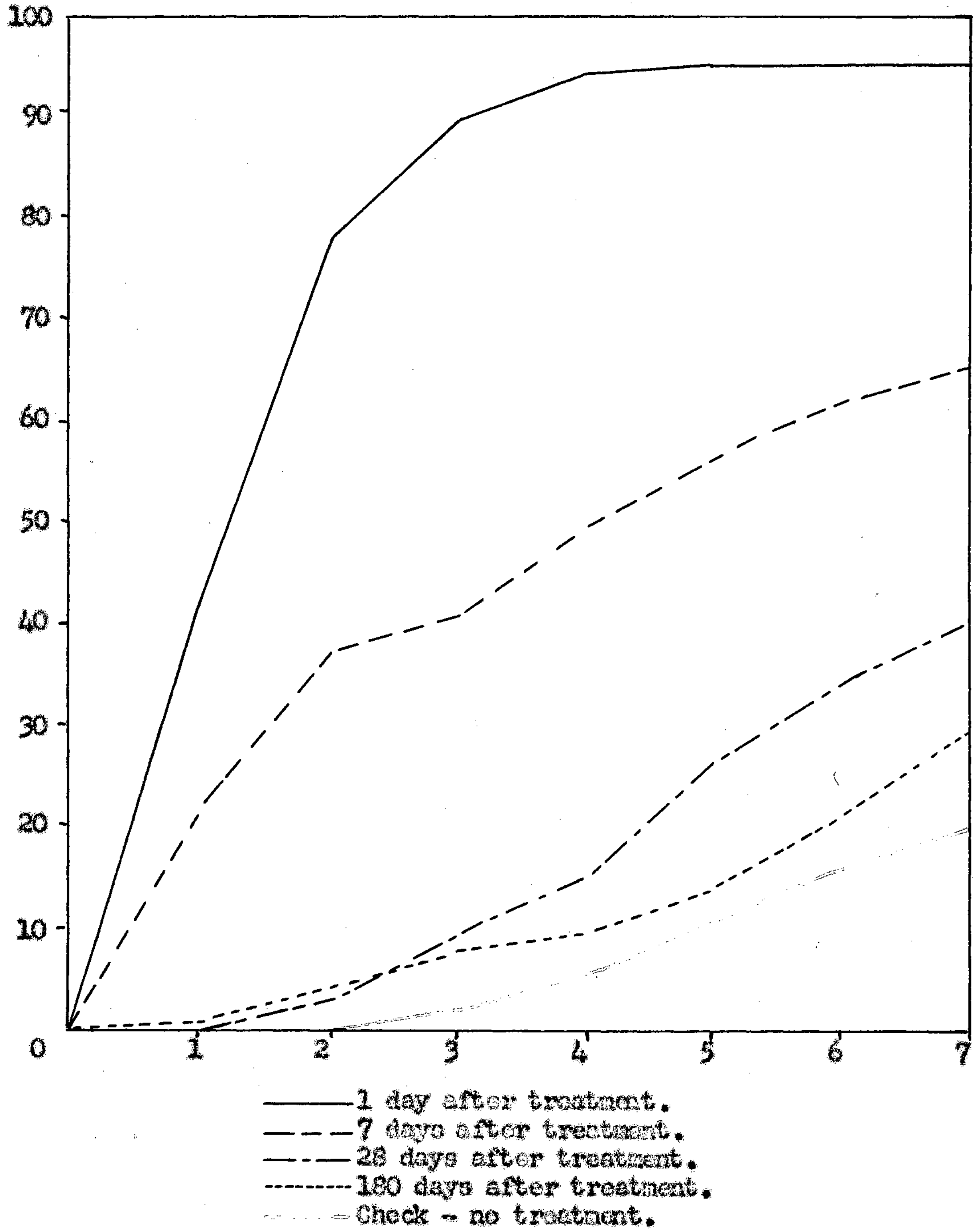
[4] F. J. Meyer, Copper 3-phenylsalicylate A Wood Preservative for the Greenhouse and Food Crate Industries, Biochemical Research Department, The Dow Chemical Company, 1950

[5] Copper 3-phenylsalicylate, The Dow Chemical Company, 1949.

Figure 4.

Mortality Curves in Per cent Dead Bees by Days When Caged Against Test Panels Treated with Coal-tar Creosote Solutions with Different Periods of Air Drying.



have indicated that accidental poisoning would result only if large quantities of the material were swallowed.

Dilution and Treatment: Copper 3-phenylsalicylate was used at five per cent by weight in all tests. The chemical for these tests was supplied by the Dow Chemical Company. No instructions were received on how to prepare the chemical for wood treatment. In Series I an attempt was made to dissolve it in mineral spirits, a suspension resulted. Since the test was started for the other preservatives it was included in this series in a suspension. Later tests it was used in the solution form. Information was received from the manufacturer as to methods of making solutions of this chemical. In all other tests the diluted preservative was made as follows: 100 grams of copper 3-phenylsalicylate was dissolved in 400 grams of amyl acetate. When completely dissolved the resulting solution was diluted with 1500 grams of mineral spirits. This made a five per cent solution by weight.

This preservative stained the test panels a light tan with a faint trace of pale green. They dried quickly, were odorless, and clean to handle.

Tests: Copper 3-phenylsalicylate was included in all of the toxicity studies. Forty-two test panels were treated with this preservative. Nine test panels were included in each of the four airing periods. Six panels were included in the fumigation studies.

Observations and Results: The test bees caged against panels treated with copper 3-phenylsalicylate showed very erratic mortality rates. The variations in death rates of bees caged against panels that had aired seven days ranged from 100 per cent at the end of twenty-four hours to zero per cent at the end of seven days exposure to the treated surface. This variation cannot be accounted for. The writer believes the results for Series III are typical of this chemical's effect on the test bees. However, the data with totals in per cent of all series are given in Table 5. In making a comparison of this adjusted data we find the effect of airing just the reverse from that of all other chemicals studied. With this material the lowest mortality was for the panels given only one day airing. Series III with one day airing at the end of the seven-day exposure had a mortality of 6.6 per cent. Panels with seven days airing at this same exposure had a mortality of 23.3 per cent. Those with twenty-eight days airing had 56.7 per cent mortality. After 180 days airing the mortality rate dropped to 13.3 per cent for this same exposure period. With the exception of the 180-day airing period, there was a gradual increase in mortality with the longer airing periods. Figure 5 shows the adjusted mortality in per cent, based on Series III, for the various air drying periods as compared with the check.

The only explanation the writer has for the variations in these data is the possibility of the copper 3-phenylsalicylate crystallizing on the surface of the treated panels thereby increasing the toxicity to the test bees. After a certain point is reached, which was not determined in these tests, the chemical loses its toxicity to the point that after 180 days after treatment it is approximately equal to the check. Further study needs to be made with this chemical to determine these points.

Copper Naphthenate

Copper naphthenate is one of the best of the newer wood preservatives. It has been used for over forty years in Denmark for the preservation of fishing nets. It was first used in the United States in 1930 as a rot preventive in wooden timbers built into commercial truck chasis. Large

Table 5

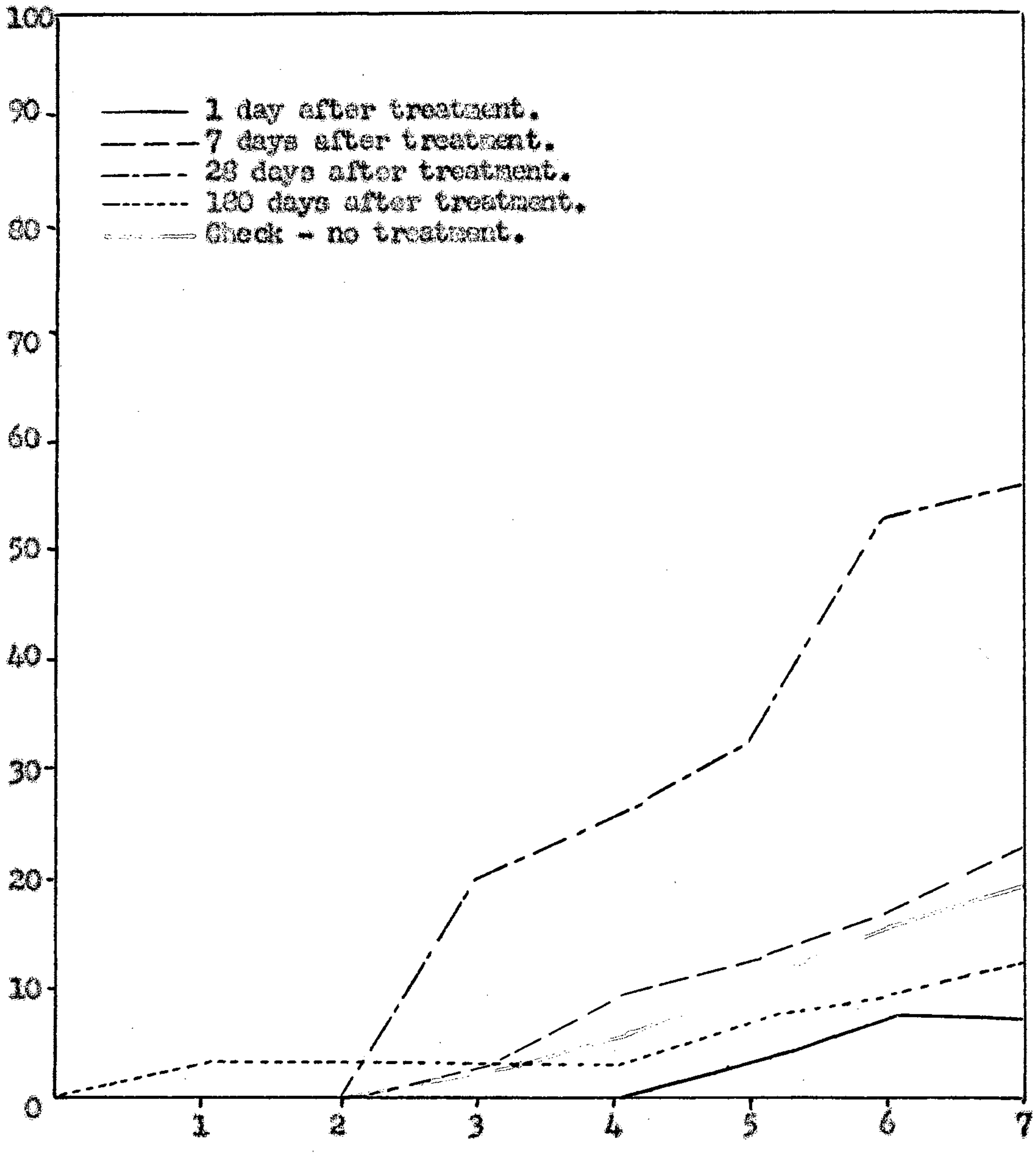
Per cent Dead Bees by Days When Caged Against Pine Panels Given a Five Minute Soak in Copper 3-Phenylsalicylate and Air Dried for Different Time Intervals

Test No.	Days Air Dried	Test Series	Per cent Dead Bees in Cages by Days 1	2	3	4	5	6	7
1-21	1*	I*	0	0	0	0	0	0	0
1-8	1	I	50	70	90	90	90	90	90
1-30	1	I	0	40	50	60	60	70	70
4-3	1	II	0	10	30	30	60	100	-
4-19	1	II	10	10	10	10	20	60	80
4-21	1	II	0	0	0	0	10	10	20
9-8	1	III	0	0	0	0	0	0	0
9-18	1	III	0	0	0	0	10	10	10
9-3	1	III	0	0	0	0	0	10	10
Average of Above in per cent			6.6	14.4	20.0	21.1	26.6	38.8	42.2
2-1	7	I	0	0	0	0	0	0	0
2-28	7	I	0	0	0	0	0	0	0
2-25	7	I	0	10	20	70	70	70	70
5-1	7	II	0	0	0	0	0	10	20
5-5	7	II	0	0	0	0	10	20	20
5-26	7	II	100	-	-	-	-	-	-
8-24	7	III	0	0	0	0	10	10	20
8-2	7	III	0	0	0	20	20	20	30
8-14	7	III	0	0	10	10	10	20	20
Average of Above in Per cent			11.1	12.2	14.4	22.2	24.4	27.7	31.1
3-28	28	I	10	70	90	90	100	-	-
3-19	28	I	0	0	10	10	10	10	10
3-21	28	I	0	70	90	90	90	90	90
6-8	28	II	10	30	60	60	60	80	80
6-18	28	II	0	0	0	10	20	20	20
6-27	28	II	0	0	0	0	0	0	10
7-28	28	III	0	0	20	20	30	50	60
7-11	28	III	0	0	20	30	30	50	50
7-16	28	III	0	0	20	30	40	60	60
Average of Above in Per cent			2.2	18.8	34.4	37.7	42.2	51.1	53.3
10-28	180	IV	0	10	10	10	20	50	50
10-11	180	IV	0	0	10	20	40	40	40
10-16	180	IV	0	0	20	20	30	40	40
11-24	180	V	0	0	0	0	0	0	0
11-2	180	V	0	0	0	0	0	0	10
11-14	180	V	0	0	10	10	10	20	20
12-8	180	VI	0	0	0	0	0	0	0
12-18	180	VI	0	0	0	0	0	0	0
12-13	180	VI	10	10	10	10	20	30	40
Average of Above in Per cent			1.1	2.2	6.6	7.7	13.3	20.0	22.2
Checks in Per cent			0	0.3	2.5	6.4	11.7	15.8	19.7

*Series I was dipped in oil suspension, other series in oil solution.

Figure 5.

Adjusted Mortality Curves in Per cent Dead Bees by Days When Caged Against Test Panels Treated with Copper 3-phenylsalicylate with Different Periods of Airing.



quantities of copper naphthenate were used during World War II for the impregnation of cotton webbing, tentage, canvas, sand bags and rope. As a dip or paint treatment copper naphthenate is used on flats and benches in greenhouses. It does not inhibit the growth of plants grown in treated containers, yet it does prevent the growth of mildew and wood destroying fungi.

Wood may be painted, dipped, or pressure treated with copper naphthenate solutions. Field tests have shown this chemical to give good protection from rots and termite attack.

Physical Properties: Copper naphthenate is produced by adding a copper solution to sodium naphthenate. It is soluble in organic solvents and decomposes in the presence of strong acid or alkali. It hydrolyzes slowly to form copper hydroxide and free naphthenic acid, both of which are toxic to wood-destroying fungi. It is insoluble in water and does not leach from treated wood placed in contact with the soil.[6] Copper naphthenate cannot be used on or near rubber products as the copper in the solution breaks down the rubber.

Copper naphthenate may be incorporated into paints, varnishes and waxes. It is used in concentrations from one to five per cent in organic solvents. The higher concentrations are used for the brush treatment, and the lower ones for dipping and pressure treating. The copper naphthenate solution is a bright green color and imparts a green color to the treated material. It will bleed through the first coat of paint, but not through the second or third coats. Beehives dipped in copper naphthenate solution when given the first coat of white paint had a pale green color; however, the second coat of white paint remained white. Not all commercial

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[6] P. T. Smith, 1938. Copper Naphthenate, Soap. 14(11):86-88.

preparations of copper naphthenate solutions are green in color. Many have mixtures of asphalt solutions present with copper naphthenate added in concentrations of two to three per cent. These solutions are brown in color and impart a brown color to the treated surface. They cannot be satisfactorily painted over with light colored paints.

Copper naphthenate solutions have been recommended for the treatment of beehives both in this country and in England. Harcourt[7] has recommended "Cuprinol," a commercial preparation consisting of a solution of copper or zinc naphthenate. He recommended treating both the inside and outside of the beehive. He reported no robbing occurred with the naphthenate treated hives as with the creosoted hives.

Dilutions and Treatment: "Cuprinol Number 10," a five per cent copper naphthenate solution with water repellent added, was used in Series I, III, IV, V, and VI. It was obtained from the Cuprinol Division, Darworth, Inc., Simsbury, Connecticut. The panels in Series II were treated with a 2.4 per cent copper naphthenate solution made by using 30 parts of "Soligen Copper 8%" and 70 parts of mineral spirits by weight. "Soligen Copper 8%" is a product of Advanced Solvents and Chemical Corporation, New York 16, New York.

The copper naphthenate solution penetrated the test panels rapidly and under favorable weather conditions dried quickly staining the wood a bright green. Both formulations were easy to work with. They did not irritate the skin nor have a very unpleasant odor. The treated wood had a slight musty smell for several days after treatment. This musty odor would linger on clothes and hands for several hours if they were allowed

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[7]L. A. Harcourt, 1938. Wood Preservatives for Beehives, American Bee Journal, Vol. 78, No. 12, p. 556.

to come in contact with the solution. Copper naphthenate being insoluble in water cannot be removed from the hands with soap and water. Mineral spirits removes it readily.

Tests: Copper naphthenate was included in all of the toxicity studies with the exception of the fumigation tests. Thirty-six panels were treated with the preservative, nine for each of the air drying periods.

Observations and Results: The test bees caged against panels treated with copper naphthenate showed very erratic mortality rates. Death rates of test bees on panels given one day air drying ranged from 100 per cent at the end of the twenty-four hours exposure to no mortality at the end of seven days exposure. Series II had a higher mortality rate than did Series I and III. This could have been due to two reasons. Series II was prepared by diluting a copper naphthenate concentrate, "Soligen Copper 8%", with mineral spirits, and there could have been a difference in the concentrate solvent or certain impurities. The mortality rate with Series II was highest on the panels given one and seven days airing indicating the toxic element remained on the wood during these periods. After 28 days airing, there was little or no difference between Series II and the other two series. The panels given only one day airing in Series II were wet looking at the time the bees were caged. This indicated the solvent had not evaporated as much as it had in the other series.

The writer believes the data obtained in Series I and III give an accurate account of this preserving material. In one of the preliminary tests run on October 8, 1948, using "Cuprinol" on the test panels which were treated during rainy weather, a time unfavorable for the evaporation of the solvent, the mortality rates ran 100 per cent at the end of twenty-four hours, while panels treated during the same month under favorable conditions gave a mortality equal to the check.

Using only "cuprinol" data obtained from Series I, III, IV, V, and VI at the end of seven days exposure to the test panels, we find that with one day airing, 35 per cent of the test bees were dead, with seven days airing 36.7 per cent, twenty-eight days airing 20 per cent, and with 180 days airing 28.8 per cent were dead. Figure 6 shows the mortality of these series in per cent for the various air drying periods as compared with the check. Table 6 gives the data in per cent for all tests run with copper naphthenate.

Using data obtained from Series II which was treated with diluted "Soligen Copper 8%," we find the mortality rates as follows: One day airing, 96.6 per cent; seven days airing, 76.6 per cent; and twenty-eight days airing, 40.0 per cent. The results of this series clearly indicate the necessity for an ample air drying period for this formulation before the use of treated beehive equipment.

Cuprinol Number 70 - Brown Stain

"Cuprinol Number 70" is a brown staining wood preservative that contains copper naphthenate as one of the preserving agents. The stain is recommended for outside use which is not to be painted. Manley,[8] a successful British beekeeper, recommends brown cuprinol as a treatment for beehives in place of creosote or painting. His reasons for the brown stain was it allowed the hive to warm up quickly by the sun during winter and made the hive inconspicuous, which prevented tampering with in out-apiaries. In England the dark color may be desirable, but in the United

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[8] R. O. B. Manley, 1946. Honey Farming, Faber and Faber, Ltd., London, p. 144.

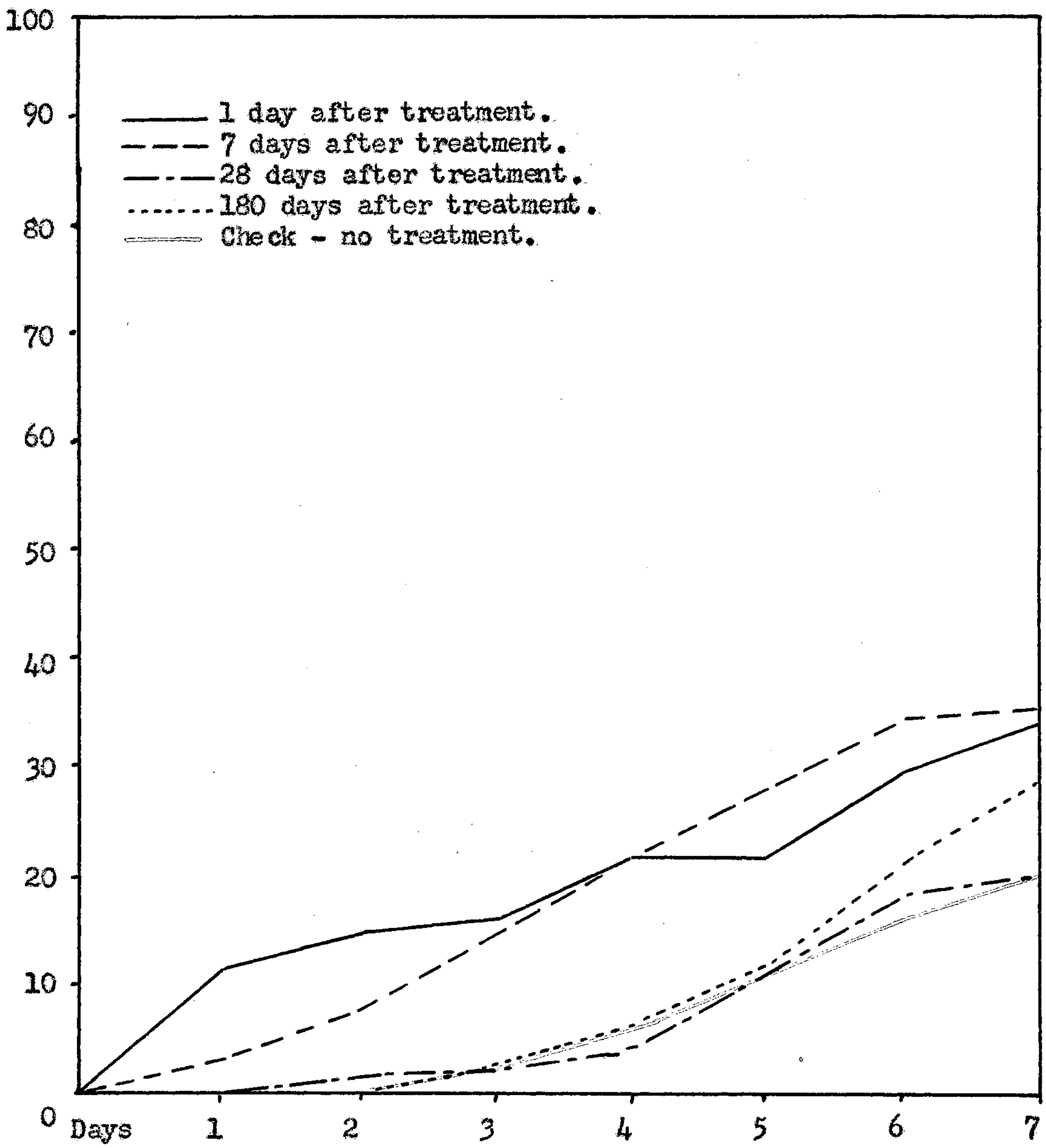
Table 6

Per cent Dead Bees by Days When Caged Against Pine Panels Given a Five Minute Soak in Copper Naphthenate and Air Dried for Different Time Intervals.

Test No.	Days Air Dried	Test Series	Per cent Dead Bees in Cages by Days 1	2	3	4	5	6	7
1-4	1	I	0	0	0	0	0	0	0
1-3	1	I	0	0	0	0	0	0	0
1-22	1	I	70	90	100	-	-	-	-
4-5	1	II	100	-	-	-	-	-	-
4-15	1	II	10	10	60	90	90	90	90
4-28	1	II	100	-	-	-	-	-	-
9-23	1	III	0	0	0	0	0	0	30
9-15	1	III	0	0	0	0	0	10	20
9-5	1	III	0	0	0	30	30	50	60
Average of Above in Per cent			31.1	33.3	40.0	46.6	46.6	50.0	55.5
2-3	7	I	0	0	0	0	0	0	10
2-8	7	I	0	0	0	0	0	10	10
2-27	7	I	20	50	80	80	100	-	-
5-7	7	II	0	0	0	0	10	20	30
5-20	7	II	10	100	-	-	-	-	-
5-27	7	II	0	0	0	0	10	40	80
8-23	7	III	0	0	0	20	40	40	40
8-18	7	III	0	0	10	20	20	20	20
8-29	7	III	0	0	0	10	10	40	40
Average of Above in Per cent			3.3	16.6	21.1	25.5	32.2	41.1	47.7
3-20	28	I	0	0	0	0	0	0	0
3-27	28	I	0	0	0	0	0	0	10
3-14	28	I	0	0	0	0	0	0	0
4-5	28	II	0	0	0	0	0	0	30
4-15	28	II	0	0	0	0	10	10	20
4-28	28	II	0	0	0	30	40	70	70
7-13	28	III	0	0	0	0	0	10	10
7-6	28	III	0	0	0	20	30	50	50
7-23	28	III	0	10	10	10	40	50	50
Average of Above in Per cent			0	1.1	1.1	6.6	13.3	21.1	30.0
10-13	180	IV	0	0	0	0	0	0	10
10-6	180	IV	0	0	0	10	10	10	20
10-23	180	IV	0	0	10	20	30	40	50
11-23	180	V	0	0	0	0	10	50	60
11-18	180	V	0	0	0	10	10	20	30
11-29	180	V	0	0	0	0	0	10	10
12-23	180	VI	0	0	0	0	0	10	10
12-15	180	VI	0	0	0	10	30	30	50
12-5	180	VI	0	0	10	10	20	20	20
Average of Above in Per cent			0	0	2.2	6.6	12.2	21.1	28.8
Checks in Per cent			0	0.3	2.5	6.4	11.7	15.8	19.7

Figure 6.

Mortality Curves in Per cent Dead Bees by Days When Caged Against Test Panels Treated with Copper Naphthenate (Cuprinol) with Different Periods of Airing.



with its hot summers, the heat absorbed by the dark hive would probably melt down the combs.

Physical Properties: "Cuprinol Number 70" - Brown Stain is a dark brown wood preservative with good penetrating properties. The preservative is patented and the exact ingredients are unknown. The active preserving chemical is copper naphthenate dissolved in an oil solvent. "Cuprinol Number 70" was easy to work with and did not have a very unpleasant odor. The stain is difficult to wash from the hands, but is easily removed with mineral spirits.

Dilutions and Treatment: "Cuprinol Number 70" was used without dilution. The test panels stained a dark brown and dried quickly after treatment. The material used in these tests was obtained from the Cuprinol Division, Darworth, Incorporated, Simsbury, Connecticut.

Tests: "Cuprinol Number 70" brown stain was included in all of the toxicity studies with the exception of the fumigation tests. Thirty-six panels were treated with this preservative, nine for each of the four air drying periods.

Observations and Results: The test bees caged against panels treated with "Cuprinol Number 70" had mortality rates comparable with the checks. Table 7 shows the mortality rates of these tests. There was little or no difference in the mortality rates between the different air drying periods. At the end of seven days exposure the mortality rates were as follows: One day airing, 16.6 per cent; seven days airing, 21.1 per cent; twenty-eight days airing, 26.6 per cent; and one hundred and eighty days airing, 21.1 per cent. There was no significant difference between the mortality rates of the checks and "Cuprinol Number 70." Figure 7 shows the mortality of bees in per cent for the various air drying periods as compared with the check.

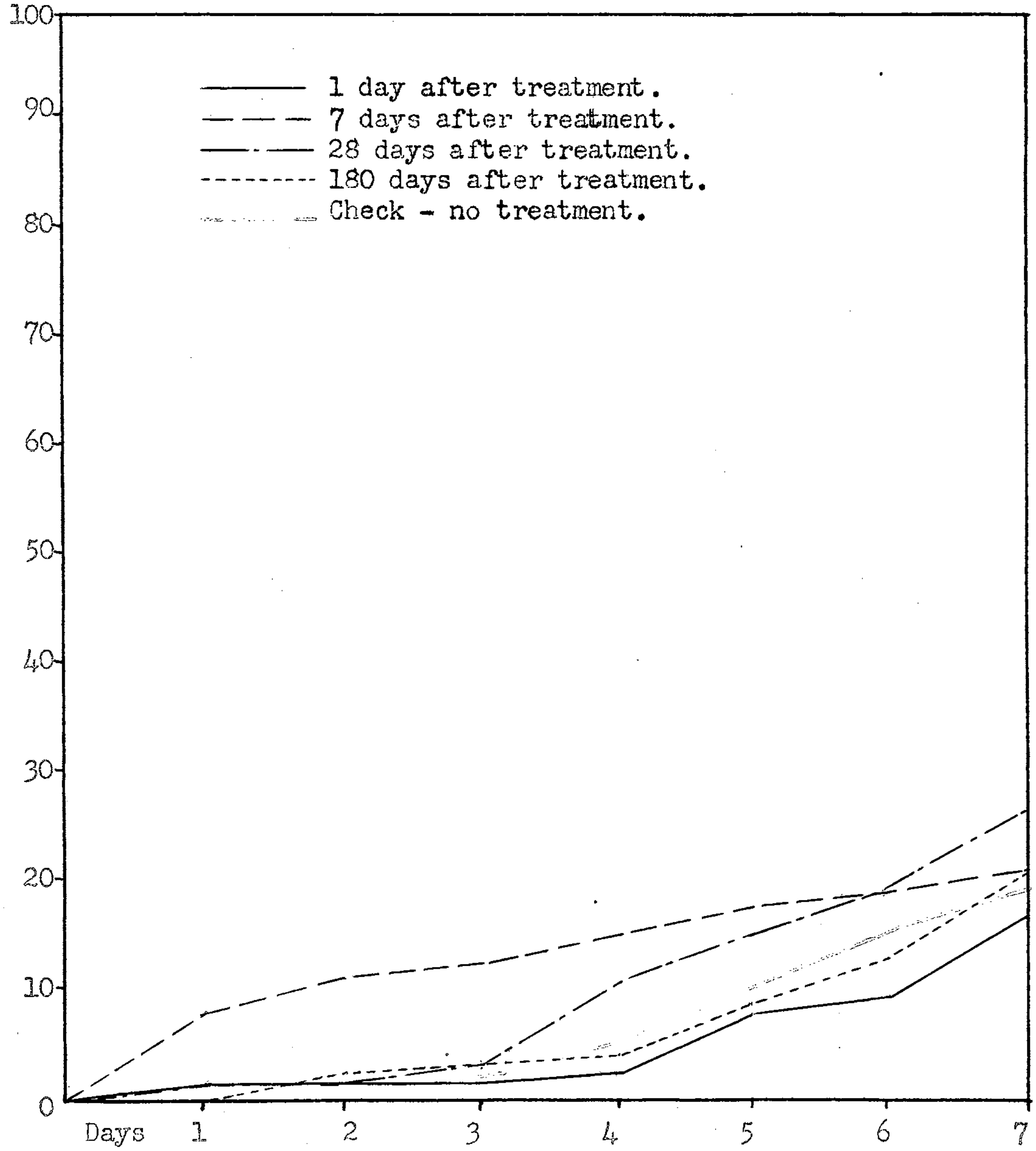
Table 7

Per cent Dead Bees by Days When Caged Against Pine Panels Given a Five Minute Soak in <u>Cuprinol No. 70</u> and Air Dried for Different Time Intervals

Test No.	Days Air Dried	Test Series	Per cent Dead Bees in Cages by Days: 1	2	3	4	5	6	7
1-18	1	I	0	0	0	0	0	0	0
1-24	1	I	0	0	0	0	0	10	10
1-25	1	I	10	10	10	10	10	10	20
4-4	1	II	0	0	0	0	0	0	30
4-24	1	II	0	0	0	0	0	0	0
4-27	1	II	0	0	0	0	20	30	40
9-19	1	III	0	0	0	10	20	20	20
9-13	1	III	0	0	0	0	0	0	10
9-29	1	III	0	0	0	0	20	20	20
Average of Above in Per cent			1.1	1.1	1.1	2.2	7.7	10.0	16.6
2-10	7	I	0	0	0	0	0	0	0
2-17	7	I	0	0	0	0	0	0	0
2-9	7	I	0	0	0	0	0	0	0
5-9	7	II	0	0	0	10	20	20	30
5-17	7	II	70	100	-	-	-	-	-
5-21	7	II	0	0	0	0	0	10	20
8-5	7	III	0	0	0	0	10	10	10
8-11	7	III	0	0	0	20	20	20	20
8-22	7	III	0	0	10	10	10	10	10
Average of Above in Per cent			7.7	11.1	12.2	15.5	17.7	18.8	21.1
3-11	28	I	0	0	0	40	40	40	40
3-24	28	I	0	0	20	20	20	20	20
3-17	28	I	0	0	0	0	0	0	0
6-1	28	II	0	0	0	0	0	0	0
6-23	28	II	0	0	0	0	0	10	20
6-26	28	II	10	10	10	10	20	30	40
7-1	28	III	0	0	0	10	10	20	30
7-7	28	III	0	0	0	0	0	0	20
7-15	28	III	0	0	0	20	50	50	70
Average of Above in Per cent			1.1	1.1	3.3	11.1	15.5	18.8	26.6
10-1	180	IV	0	0	0	0	0	10	40
10-7	180	IV	0	0	0	0	0	0	0
10-15	180	IV	0	10	20	20	20	20	30
11-5	180	V	0	0	0	0	20	20	30
11-11	180	V	0	0	0	10	10	10	10
11-22	180	V	0	10	10	10	10	10	10
12-19	180	VI	0	0	0	0	20	40	40
12-13	180	VI	0	0	0	0	0	0	20
12-29	180	VI	0	0	0	0	0	10	10
Average of Above in Per cent			0	2.2	3.3	4.4	8.8	13.3	21.1
Checks in Per cent			0	0.3	2.5	6.4	11.7	15.8	19.7

Figure 7

Mortality Curves in Per cent Dead Bees by Days When Caged Against Test Panels Treated with Cuprinol No. 70 with Different Periods of Airing.



Pentachlorophenol

The use of pentachlorophenol is a rather recent development in wood preservation. It was first produced commercially in 1936. It is usually applied as a five per cent solution in oil for the treatment of seasoned lumber against the attacks of termites, powderpost beetles, and many wood-rot organisms. This material overcomes the objectional features of creosote; namely, its color, odor, and lack of persistence.

Accelerated stake tests have shown pentachlorophenol to be a very satisfactory wood preservative in resisting wood-rots and termite attack. In 1947 the domestic consumption of this material for wood preservation amounted to 6,909,000 pounds. It is used as a brush treatment, dip treatment and in pressure treatment of lumber and poles. Much millwork, telephone posts, fence posts, and other wooden articles are treated with pentachlorophenol. Many commercial formulations of pentachlorophenol contain a water repellent and sealing material. A formulation of this nature was used in these tests.

Pentachlorophenol has been suggested as a treatment for beehives by Dyce.[9] He suggests the dipping of the hive parts in the solution and allowing to dry one to two weeks before use. He says "there is no indication that pentachlorophenol is more harmful to bees than creosote." In unpublished data of the G. B. Lewis Company of Watertown, Wisconsin, pentachlorophenol was found to be as follows: relatively non-toxic as far as humans were concerned, a preservative that would not taint the honey, and one that would in no way injure the bees. The fact that certain individuals developed dermatitis when coming in contact with wood treated

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[9] E. J. Dyce, 1951, Wood Preservatives and their Application, American Bee Journal, Vol 91, No. 5, pp. 192-93.

with pentachlorophenol caused this company to use a different preservative on their manufactured beehive equipment that is treated for rot resistance. No experimental data has been found in the literature as to the relative toxicity of this material to the honeybee.

Physical Properties: Pentachlorophenol is a white crystalline compound in the pure form. In the technical grades it is darker colored with a slightly lower boiling point. The crystals are needle shaped and sublime with a characteristic odor. It weighs approximately 55 pounds per cubic foot, and crystalizes around 180 degrees centigrade. It has a low vapor pressure and almost insoluble in water, both of which make it a lasting wood preservative. At 86 degrees centigrade the vapor pressure is less than 0.0005 mm. of mercury, and its solubility in water is less than 0.002 per cent. Pentachlorophenol is soluble in organic solvents in various amounts. Light fuel oil takes up 2.5 to 3.5 per cent, pine oil 32 per cent, and 95 per cent ethyl alcohol, 47.5 per cent by weight. A thousand board feet of dry lumber will absorb twelve to fifteen gallons of five per cent pentachlorophenol solution when immersed for three minutes.

One objection of pentachlorophenol is that it is more or less irritating to the skin and mucous membranes if sufficient contact is permitted. It is recommended that operators using this preservative use protective gloves, aprons, etc., made of synthetic rubber. The writer noticed no detrimental effect from using the 5 per cent solution in dipping hive parts. The material came in contact with his hands, and no redness or rash occurred. Some people, however, are very sensitive to pentachlorophenol and break out in a serious rash upon contact.

The water soluble sodium salt of pentachlorophenol, sodium pentachlorophenate, is also used as a wood protectant, especially for powder-post beetles and wood staining fungi. This material does not have the penetrating properties into wood as the oil soluble pentachlorophenol.

<u>Dilution and Treatment</u>: The pentachlorophenol used in these tests was supplied by the Chapman Chemical Company, Memphis, Tennessee. The trade name was "Permatox WR." It contained five per cent pentachlorophenol and a water repellent material in an oil solvent. The material was ready to use and was used without dilution. "Permatox WR" can be had in a two to one and a three to one concentrate, which can be diluted with mineral spirits with satisfactory results. No difference was detected by the writer in the effects of the two materials on the honeybee. Good penetration was obtained by the five-minute dip treatment. The test panels when wet had a slight tan color, which gradually faded away during the air drying period. There was no objectional odor or other features noticed in handling the "Permatox WR" solution of pentachlorophenol.

<u>Tests</u>: Pentachlorophenol was included in all of the toxicity studies. Forty-two test panels were treated with this preservative. Nine test panels were included in each of the four airing periods. Six panels were included in the fumigation studies.

<u>Observations and Results</u>: The test bees caged against the panels treated with pentachlorophenol had a gradual reduction in mortality with the increase of the air drying time. At the end of seven days exposure to the treated panels that were given one day airing there was seventy-one per cent mortality. After seven days airing the mortality was fifty-nine per cent and after twenty-eight days airing the mortality was reduced to thirty-one per cent. After twenty-eight days airing there was no significant difference between the treated panels and the check. In the 180-day tests there was an increase of thirteen per cent in mortality over the panels given the twenty-eight days airing period. This variation was unaccounted for.

Table 8 gives the data in per cent for all tests run with pentachlorophenol. There was some difference in mortality of test bees in the various series. There was a gradual increase in mortality with the increase in exposure time to the treated panels. This occurred in all series and in all air drying periods. Figure 8 shows the mortality of bees on pentachlorophenol panels in per cent for the various air drying periods as compared with the check.

Zinc Naphthenate

Zinc naphthenate is one of the newer preservatives and is very similar to copper naphthenate. It has been used in place of copper naphthenate where a colorless preservative was required. Zinc naphthenate is superior to copper in the treatment of cordage which must come in contact with rubber goods. Copper compounds cause rubber goods to break down, and for this reason they are unsatisfactory for materials that come in contact with rubber. During World War II net and guide ropes of barrage balloons were treated with zinc naphthenate solutions. Zinc naphthenate is not used as a wood preservative as much as copper naphthenate is. It is used primarily to treat tentage, cordage, shade cloth, reaper bands, and like materials.

Physical Properties: Zinc naphthenate combines the lesser fungicidal action of zinc metal with the active fungicidal action of the naphthenic acid radical. In solution zinc naphthenate is practically colorless, is water repellent and is resistant to leaching. It has good penetrating power when used with low viscosity solvents. It is readily soluble in low cost petroleum solvents, such as mineral spirits, kerosene, lubricating

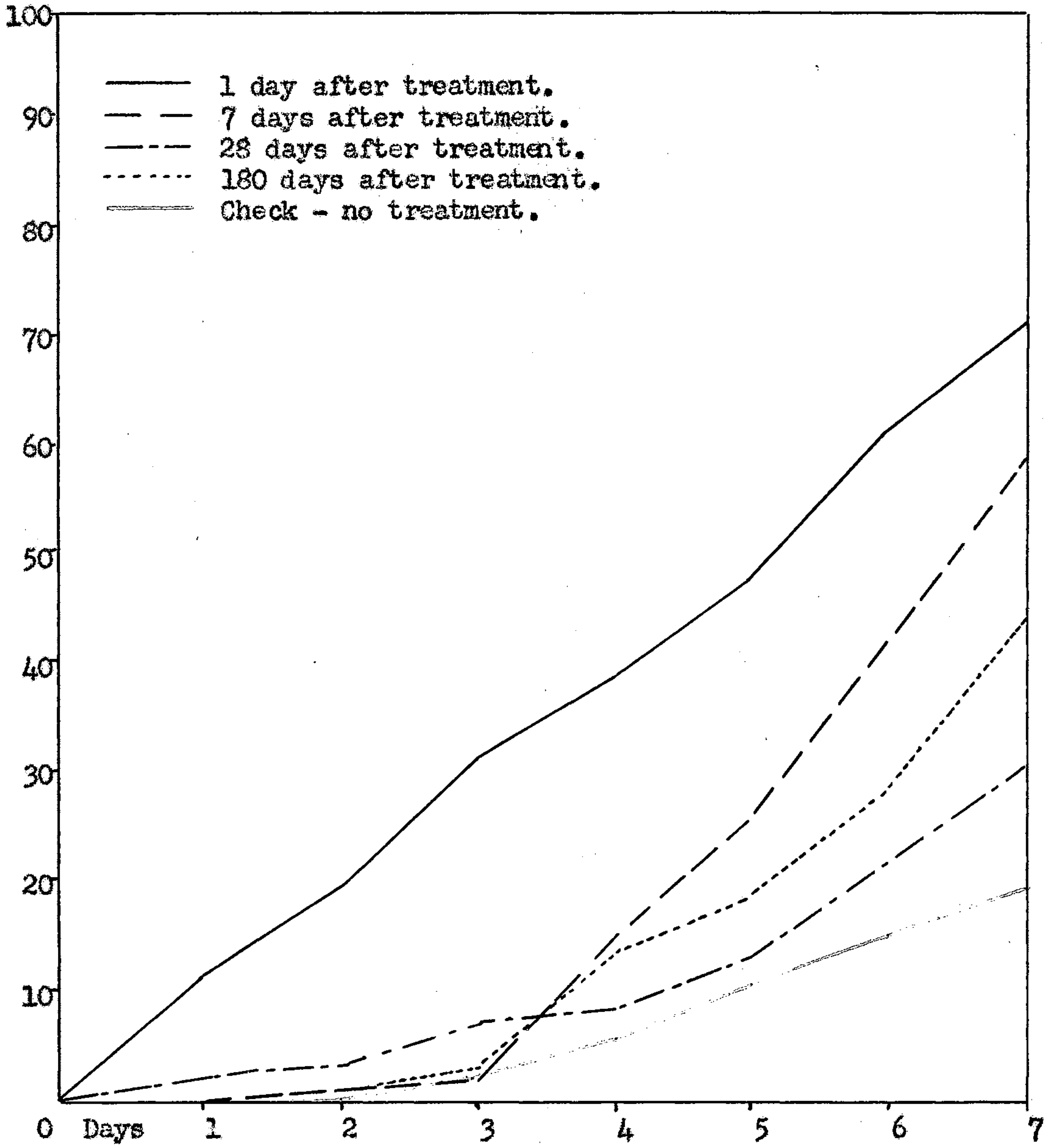
Table 8

Per cent Dead Bees by Days When Caged Against Pine Panels Given a Five Minute Soak in Pentachlorophenol and Air Dried for Different Time Intervals.

Test No.	Days Air Dried	Test Series	Per cent Dead Bees in Cages by Days 1	2	3	4	5	6	7
1-23	1	I	100	-	-	-	-	-	-
1-12	1	I	0	0	10	10	10	50	80
1-6	1	I	0	10	10	20	30	50	60
4-10	1	II	10	40	70	80	90	90	100
4-12	1	II	0	10	20	20	20	20	40
4-13	1	II	0	20	50	60	80	100	-
9-26	1	III	0	0	20	40	70	100	-
9-20	1	III	0	0	0	10	10	10	20
9-17	1	III	0	0	10	10	20	30	40
Average of Above in Per cent			12.2	20.0	32.2	38.8	47.7	61.1	71.1
2-22	7	I	0	0	0	30	30	40	60
2-6	7	I	0	0	0	20	20	40	50
2-19	7	I	0	0	0	0	0	50	100
5-11	7	II	0	0	0	20	30	60	90
5-16	7	II	0	0	0	10	40	40	40
5-24	7	II	0	10	20	40	70	70	70
8-19	7	III	0	0	0	0	0	10	20
8-16	7	III	0	0	0	0	30	50	50
8-6	7	III	0	0	0	20	20	20	50
Average of Above in Per cent			0	1.1	2.2	15.5	26.6	42.2	58.8
3-13	28	I	0	0	0	0	10	10	10
3-4	28	I	0	0	0	0	0	20	40
3-2	28	I	0	0	0	0	0	30	40
6-7	28	II	0	10	10	10	20	30	40
6-21	28	II	0	0	0	0	0	0	10
6-24	28	II	20	20	20	30	40	50	60
7-25	28	III	0	0	10	10	10	10	30
7-10	28	III	0	0	0	0	10	20	20
7-14	28	III	0	0	20	20	30	30	30
Average of Above in Per cent			2.2	3.3	6.6	7.7	13.3	22.2	31.1
10-25	180	IV	0	0	20	30	50	60	70
10-10	180	IV	0	10	10	40	40	50	70
10-14	180	IV	0	0	0	30	30	50	60
11-19	180	V	0	0	0	20	30	30	40
11-16	180	V	0	0	0	0	0	0	10
11-6	180	V	0	0	0	10	20	30	30
12-26	180	VI	0	0	0	0	0	30	90
12-20	180	VI	0	0	0	0	0	10	10
12-17	180	VI	0	0	0	0	0	0	20
Average of Above in Per cent			0	1.1	3.3	14.4	18.8	28.8	44.4
Checks in Per cent			0	0.3	2.5	6.4	11.7	15.8	19.7

Figure 8.

Mortality Curves in Per cent Dead Bees by Days When Caged Against test Panels Treated with Pentachlorophenol with Different Periods of Airing.



oil, waste crank case oil, and paint drying oils.[10]

Zinc naphthenate is used as a preservative in concentrations of from one to five per cent as a solution in organic solvents. The concentrate used in these tests before dilution had a metal content of eight per cent zinc, weighed 8.4 pounds to the gallon, had a specific gravity of 1.01, a solids by weight content of 63 per cent and a flash point minimum of 110 degrees F.

Dilution and Treatment: The 3.2 per cent solution of zinc naphthenate used in these tests was made by using 40 parts of "Soligen Zinc Naphthenate 8%" concentrate with 60 parts of mineral spirits by weight. The "Soligen Zinc Naphthenate" concentrate was a product of Advanced Solvents and Chemical Corporation, New York 16, New York.

This solution of zinc naphthenate penetrated the test panels rapidly and under favorable weather conditions dried quickly. The test panels were not stained, and after drying looked similar to untreated wood. This formulation was pleasant to work with and did not have an objectional odor nor did it irritate the skin.

Tests: Zinc naphthenate was included in all of the toxicity studies with the exception of the fumigations tests. Thirty-six panels were treated with the preservative for these tests.

Observation and Results: The test bees caged against panels treated with zinc naphthenate had a mortality rate equal to the check with the exception of those in Series I which had air dried for only one day. This one series had a mortality rate of 90 per cent at the end of the seven-day exposure period. While for the same air drying period Series II and III

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[10] Copper Naphthenate - Zinc Naphthenate, Advance Solvents & Chemical Corp., New York, 1947.

had a mortality rate of only 16 per cent which was equal to the check. The high mortality of this one series cannot be accounted for by the writer. If the data for this preservative is adjusted by removing Series I, we find the mortality rates for the different air drying periods to be as follows: one day air drying, 16 per cent, and the other three air drying periods 17.7 per cent. The total mortality for the check of all series was 19.7 per cent, which was two per cent more than the mortality that occurred on the zinc naphthenate panels.

Table 9 gives the data in per cent for all tests run with the zinc naphthenate solution. Figure 9 shows the mortality of the test bees on zinc naphthenate treated panels in per cent for the various air drying periods as compared with the check. Table 10 gives the data in per cent for all checks included in these tests.

Table 9

Per cent Dead Bees by Days When Caged Against Pine Panels Given a Five Minute Soak in Zinc Naphthenate and Air Dried for Different Time Intervals

Test No.	Days Air Dried	Test Series	Per cent Dead Bees in Cages by Days 1	2	3	4	5	6	7
1-29	1	I	70	90	90	90	90	90	100
1-2	1	I	20	70	70	70	70	70	70
1-9	1	I	40	80	80	90	100	-	-
4-2	1	II	0	0	0	0	0	0	0
4-11	1	II	0	10	30	30	30	30	30
4-23	1	II	0	0	0	0	0	0	0
9-25	1	III	0	0	0	0	0	0	0
9-14	1	III	0	0	20	30	40	50	70
9-24	1	III	0	0	0	0	0	0	0
Average of Above in Per cent			14.4	27.7	32.2	34.4	36.6	37.7	41.1
2-22	7	I	0	0	0	0	0	0	0
2-2	7	I	0	0	0	0	0	0	0
2-18	7	I	0	0	0	0	0	10	10
5-2	7	II	0	0	0	0	0	0	0
5-14	7	II	0	0	0	0	0	20	20
5-19	7	II	0	0	0	0	0	0	10
8-28	7	III	0	0	0	10	20	20	20
8-10	7	III	0	0	0	0	30	40	40
8-27	7	III	0	0	0	0	20	50	60
Average of Above in Per cent			0	0	0	1.1	7.7	15.5	17.7
3-16	28	I	0	0	0	0	0	10	10
3-29	28	I	0	0	0	0	0	0	0
3-1	28	I	0	0	0	0	0	0	0
6-11	28	II	0	0	0	10	30	30	30
6-17	28	II	0	0	0	0	20	30	50
6-20	28	II	0	10	10	10	20	20	20
7-4	28	III	0	0	0	10	10	10	10
7-19	28	III	0	0	0	10	10	30	30
7-18	28	III	0	0	0	0	10	10	10
Average of Above in Per cent			0	1.1	1.1	4.4	11.1	15.5	17.7
10-4	180	IV	0	0	0	0	0	0	0
10-19	180	IV	20	30	40	40	70	90	90
10-18	180	IV	0	0	0	0	10	10	10
11-28	180	V	0	0	0	0	0	10	10
11-10	180	V	0	0	0	10	10	30	30
11-27	180	V	0	0	0	10	10	10	10
12-25	180	VI	0	0	0	0	0	0	0
12-14	180	VI	0	0	0	0	0	0	10
12-24	180	VI	0	0	0	0	0	0	0
Average of Above in Per cent			2.2	3.3	4.4	6.6	11.1	16.6	17.7
Checks in Per cent			0	0.3	2.5	6.4	11.7	15.8	19.7

Figure 9.

Mortality Curves in Per cent Dead Bees by Days When Caged Against Test Panels Treated with Zinc Naphthenate with Different Periods of Airing.

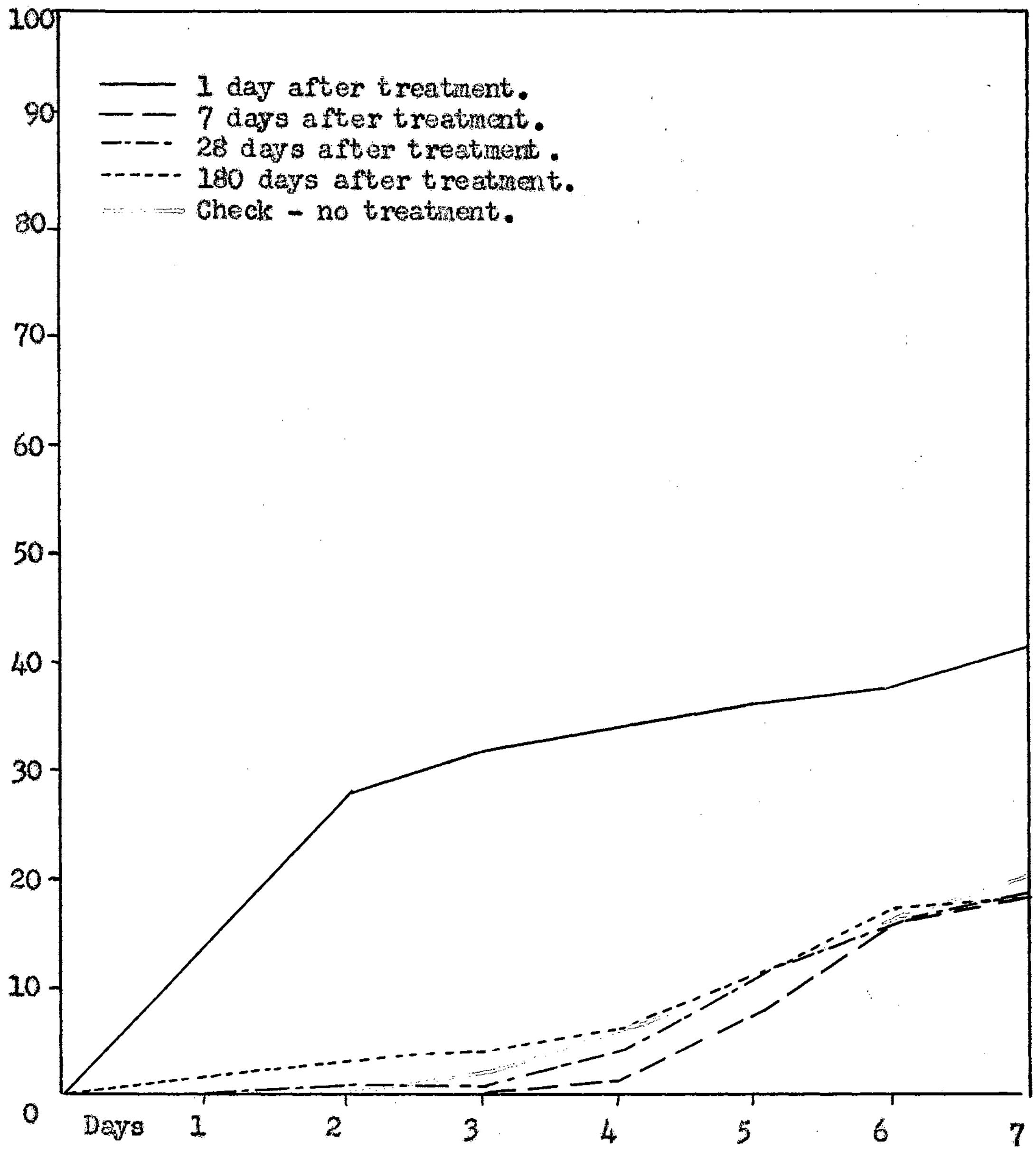


Table 10

Per cent Dead Bees by Days When Caged Against Pine Panels with no treatment.

Test No.	Days Air Dried	Test Series	Per cent Dead Bees in Cages by Days 1	2	3	4	5	6	7
1-17	1	I	0	0	0	0	0	0	10
1-11	1	I	0	0	0	0	0	0	0
1-27	1	I	0	0	0	0	0	0	0
4-6	1	II	0	0	0	0	20	40	50
4-22	1	II	0	0	0	0	30	30	40
4-29	1	II	0	0	10	10	40	50	80
9-10	1	III	0	0	0	10	10	30	30
9-21	1	III	0	0	0	0	10	10	10
9-7	1	III	0	0	0	20	30	30	30
Average of Above in Per cent			0	0	1.1	4.4	15.5	21.1	27.7
2-16	7	I	0	0	0	0	0	10	20
2-12	7	I	0	0	0	0	0	0	0
2-13	7	I	0	0	0	0	0	0	0
5-4	7	II	0	0	0	0	10	10	10
5-13	7	II	0	0	0	20	30	30	30
5-28	7	II	0	0	0	10	20	20	20
8-12	7	III	0	0	0	10	10	10	10
8-25	7	III	0	0	10	10	10	20	20
8-21	7	III	0	10	10	20	20	20	20
Average of Above in Per cent			0	1.1	2.2	7.7	11.1	13.3	14.4
3-23	28	I	0	0	0	0	0	0	10
3-18	28	I	0	0	0	0	0	0	0
3-3	28	I	0	0	0	0	0	50	50
6-14	28	II	0	0	10	20	20	20	20
6-16	28	II	0	0	0	0	30	40	50
6-29	28	II	0	0	0	0	10	10	40
7-12	28	III	0	0	30	30	30	30	30
7-27	28	III	0	0	0	0	10	10	10
7-30	28	III	0	0	0	20	20	20	20
Average of Above in Per cent			0	0	4.4	7.7	13.3	20.0	25.5
10-12	180	IV	0	0	0	0	0	0	0
10-27	180	IV	0	0	0	10	10	10	10
10-30	180	IV	0	0	10	10	20	30	40
11-12	180	V	0	0	10-	20	20	20	20
11-25	180	V	0	0	0	0	0	0	0
11-21	180	V	0	0	0	10	10	20	20
12-10	180	VI	0	0	0	0	0	0	0
12-21	180	VI	0	0	0	0	0	0	10
12-7	180	VI	0	0	0	0	0	0	0
Average of Above in Per cent			0	0	2.2	5.5	6.6	8.8	11.1
Average of all Checks Above			0	0.3	2.5	6.4	11.7	15.8	19.7

COMPARISON OF WOOD PRESERVATIVES TESTED

The comparative results of the nine wood preservatives tested are given in Tables 11, 12, and 14. The analysis of variance for the mortality rates for Series I, II and III, is given in Table 13. A summation of the effects of the different air drying periods for all preservatives is shown in Figure 10.

Comparison of the one-day air drying period: Three of the wood preservatives caused mortality rates which were highly significant when compared with the check when test bees were exposed to treated panels after one day air drying. They were carbolineum, coal-tar creosote, and pentachlorophenol. Carbolineum caused the highest mortality rates with 100 per cent dead bees at the end of a three-day exposure against the treated panels. Coal-tar creosote caused 95.5 per cent and pentachlorophenol 71.1 per cent mortality at the end of seven day exposure. Copper naphthenate had a significant difference causing a mortality rate of 55.5 per cent at the end of seven days exposure. (Table 11). There were no significant differences between the check and the other five preservatives when given a one day airing period. (Table 14).

Comparison of the seven-day air drying period: Two materials were highly significant and one was significant in causing mortality rates after seven days air drying before contact with the test bees. Carbolineum and coal-tar creosote were highly significant causing mortality rates of 84.4 and 65.5 per cent respectively, at the end of seven days exposure. Pentachlorophenol had a significant difference in mortality with 58.8 per cent. There was no significant difference between the check and the other six materials.

Comparison of the twenty-eight day air drying period: Copper 3-phenylsalicylate was the only material with a significant difference in mortality when the test panels were given twenty-eight days air drying before exposure to the test bees. This material acted differently from the other preservatives in that the mortality rates increased with the longer air drying period of twenty-eight days. At the end of one hundred and eighty days, however, the mortality rates caused by this material were equal to the check. The preservatives which were highly significant after one and seven days air drying showed no significant difference from the check after the twenty-eight day air drying period.

Comparison of the one hundred and eighty days air drying period: All preservatives tested showed no significant difference in test bee mortality when caged against panels which had air dried one hundred and eighty days.

Summary: Four wood preservatives included in these tests showed no significant difference from the check in the four air drying periods (Table 14). These materials were "celcure," chromated zinc chloride, "cuprinol # 70," and zinc naphthenate. Two materials, carbolineum and coal-tar creosote, showed highly significant differences when test bees were caged against treated panels which had received one and seven-day air drying periods. Pentachlorophenol caused mortality rates which were highly significant on one-day air dried panels, and a significant difference on panels air dried for seven days. With the exception of copper 3-phenylsalicylate, the toxicity to test bees was gradually reduced with the increase of the air drying time. This material was the only preservative that caused a significant increase in mortality rates on panels air dried for twenty-eight days, but it was equal to the check on panels air dried for one hundred and eighty days. There was no significant differences in mortality rates on panels treated with the nine test preservatives and air dried one hundred and eighty days and the check.

Table 11

Per cent Dead Bees by Days When Caged Against Pine Panels Given a Five Minute Soak in Various Wood Preservatives and Air Dried for Different Time Intervals

Preservative Used	Days Air Dried	Per cent Dead Bees in Cages by Days: 1	2	3	4	5	6	7
Carbolineum	1	40.0	86.6	100.0	-	-	-	-
	7	3.3	13.3	52.2	67.7	74.4	77.7	84.4
	28	0.0	0.0	5.5	13.3	23.3	30.0	38.8
	180	1.1	6.6	10.0	21.1	28.8	34.4	36.6
Celcure	1	0.0	0.0	1.1	4.4	8.8	17.7	25.5
	7	0.0	0.0	4.4	5.5	8.8	13.3	20.0
	28	1.1	1.1	3.3	8.8	14.4	18.8	24.4
	180	2.2	3.3	4.4	7.7	12.2	20.0	25.5
Chromated Zinc Chloride	1	0.0	0.0	2.2	5.5	21.1	24.4	32.2
	7	0.0	0.0	1.1	5.5	8.8	15.5	26.6
	28	0.0	0.0	1.1	7.7	14.4	16.6	26.6
	180	1.1	2.2	5.5	6.6	11.1	16.6	20.0
Coal-Tar Creosote	1	42.2	77.7	90.0	94.4	95.5	95.5	95.5
	7	22.2	37.7	41.1	50.0	56.6	62.2	65.5
	28	0.0	3.3	10.0	15.5	26.6	34.4	40.0
	180	1.1	4.4	7.7	10.0	14.4	21.1	28.8
Copper 3-phenyl-salicylate	1	6.6	14.4	20.0	21.1	26.6	38.8	42.2
	7	11.1	12.2	14.4	22.2	24.4	27.7	31.1
	28	2.2	18.8	34.4	37.7	42.2	51.1	53.3
	180	1.1	2.2	6.6	7.7	13.3	20.0	22.2
Copper Naphthenate	1	31.1	33.3	40.0	46.6	46.6	50.0	55.5
	7	3.3	16.6	21.1	25.5	32.2	41.1	47.7
	28	0.0	1.1	1.1	6.6	13.3	21.1	30.0
	180	0.0	0.0	2.2	6.6	12.2	21.1	28.8
Cuprinol No.70 Brown Stain	1	1.1	1.1	1.1	2.2	7.7	10.0	16.6
	7	7.7	11.1	12.2	15.5	17.7	18.8	21.1
	28	1.1	1.1	3.3	11.1	15.5	18.8	26.6
	180	0.0	2.2	3.3	4.4	8.8	13.3	21.1
Pentachlorophenol	1	12.2	20.0	32.2	38.8	47.7	61.1	71.1
	7	0.0	1.1	2.2	15.5	26.6	42.2	58.8
	28	2.2	3.3	6.6	7.7	13.3	22.2	31.1
	180	0.0	1.1	3.3	14.4	18.8	28.8	44.4
Zinc Naphthenate	1	14.4	27.7	32.2	34.4	36.6	37.7	41.1
	7	0.0	0.0	0.0	1.1	7.7	15.5	17.7
	28	0.0	1.1	1.1	4.4	11.1	15.5	17.7
	180	2.2	3.3	4.4	6.6	11.1	16.6	17.7
Check - no treatment		0.0	0.3	2.5	6.4	11.7	15.8	19.7

Table 12

Comparative Average Mortality of Various Wood Preservatives to Check

Preservative Used	Days Air Dried Before Exposure 1	7	28	180	Average Total
Carbolineum	30.0	25.3	11.7	11.7	19.3
Celcure	7.7	6.0	7.3	7.6	7.2
Chromated Zinc chloride	9.7	8.0	8.0	6.0	7.9
Coal-tar creosote	28.7	19.7	12.0	8.7	17.3
Copper 3-phenylsalicylate	12.7	9.3	16.0	6.7	11.2
Copper naphthenate	16.7	14.5	9.0	8.7	12.2
Cuprinol #70	5.0	7.3	8.0	6.3	8.8
Pentachlorophenol	21.3	17.7	9.3	13.3	15.4
Zinc naphthenate	12.3	5.3	5.3	5.3	7.0
Check					7.1

Least difference for significance (19:1) - 7.4
(99:1) - 9.8

Table 13

Analysis of Variance for Rate of Mortality in Series I, II, and III for Nine Wood Preservatives

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	89	6,624.5	
Series	2	678.2	339.1
Treatment	29	4,170.5	143.8
Preservatives	9	2,684.1	298.2
Time	2	509.6	254.8
Time Preservative	18	976.8	54.3
Error	58	1,775.8	30.6

Table 14

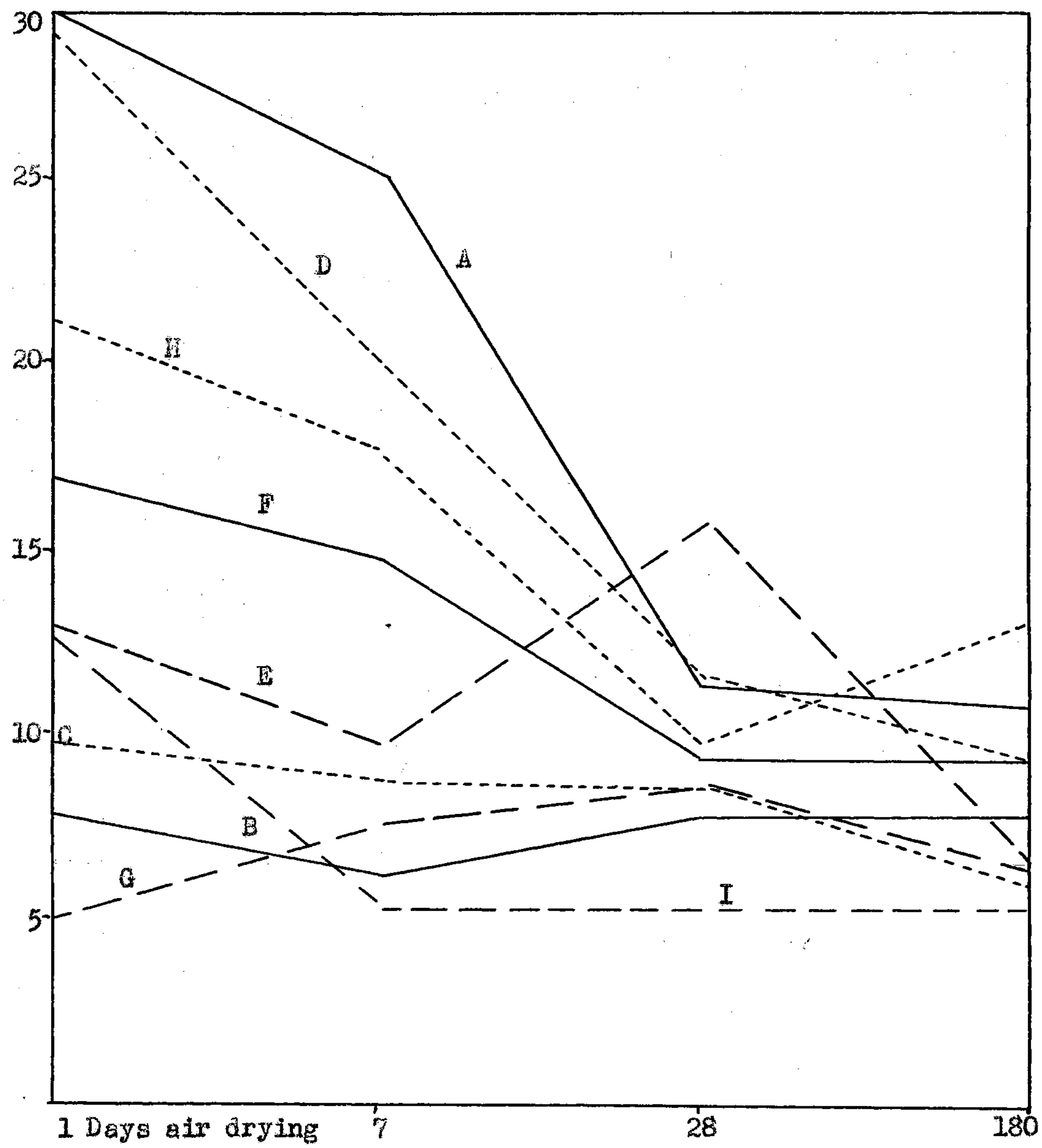
Summary of the Effect of All Tested Formulations on Mortality Rates of Test Bees

Preservative Tested	Days after Treatment Test Bees Caged			
	1 Day	7 Days	28 Days	180 Days
Carbolineum	**	**	-	-
Celcure	-	-	-	-
Chromated Zinc chloride	-	-	-	-
Coal-tar creosote	**	**	-	-
Copper 3-Phenylsalicylate	-	-	*	-
Copper naphthenate	*	-	-	-
Cuprinol #70	-	-	-	-
Pentachlorophenol	**	*	-	-
Zinc naphthenate	-	-	-	-

** Highly significant. (99-1)
 * Significant. (19-1)
 - non significant.

Figure 10.

A Comparison of the effects of different air drying periods on nine wood preservatives on contact bee mortality.



A - Carbolineum
B - Celcure
C - Chromated Zinc chloride
D - Coal-tar creosote
E - Copper 3-phenylsalicylate
F - Copper naphthenate
G - Cuprinol #70
H - Pentachlorophenol
I - Zinc naphthenate
- - - Check

FUMIGATION STUDIES WITH CERTAIN WOOD PRESERVATIVES

The fumes given off by some of the wood preservatives were very noticeable in the dipping and handling of the test panels. Test bees on panels treated with strong smelling preservatives ran rapidly over the surface of the cage and beat their wings rapidly for several hours after being caged. This activity was very noticeable in the test cages which had the highest mortality rates. To determine whether the test bees were being killed by contact with the treated surface or by the fumes given off by the treated surface, two series of tests, Number VII and IX, were conducted.

Equipment and Methods: The test panels and the methods used in these tests were the same as those described for the contact tests. The special double screened cage was used to prevent the test insects from coming in contact with the treated surface. Four wood preservatives and a check were included in each of these series. The wood preservatives tested were carbolineum, coal-tar creosote, copper 3-phenyl-salicylate and pentachlorophenol. The test panels were given a five minute soak in the preservative and then air dried for twenty-four hours. After the air drying period, the double screened cages were nailed in place, and the test bees caged. Each preservative and the check were replicated three times in each series, making a total of 30 test panels. The test bees caged against the panels were handled in the same manner as already described, except the exposure period was reduced to five days.

The exposure time was reduced because the writer felt if toxic fumes were present they would affect the bees within a five day period.

Observations and Results: The test bees immediately after being caged over the wood surfaces treated with carbolineum and coal-tar creosote were very excited and nervous. They ran over the surface of the cage and made a buzzing sound with their wings for several hours. These materials were coal tar derivatives and smelled very strongly of creosote. Bees in these cages fed very little during the five-day period. At the end of the first day many of the test bees were found on the bottom screen unable to walk. Their legs and mouth parts moved slowly and they remained on their backs until they died. Carbolineum, which had the stronger odor, affected the activity of the bees more than did the coal-tar creosote. The bees caged over the other test chemicals ran over the cages for a short time after being caged, and then started feeding on the sugar candy. With the exception of the carbolineum and coal-tar creosote cages, it was necessary to add candy to all the other cages every day during the exposure period. Apparently no feeding took place in the creosote and carbolineum cages after the second day.

The results of these tests are given in Table 15. They indicate that wood preservatives containing coal-tar products produce fumes that cause an injurious effect on bees when caged near a treated surface. Carbolineum caused greater mortality than any of the other preservatives tested. The mortality caused by this preservative at the end of the five-day exposure to the fumes was an average of 85 per cent for both series. Coal-tar creosote was next to carbolineum causing a mortality of 62 per cent for the same period. Copper 3-phenylsalicylate was equal to the check, and pentachlorophenol was slightly above the check, causing

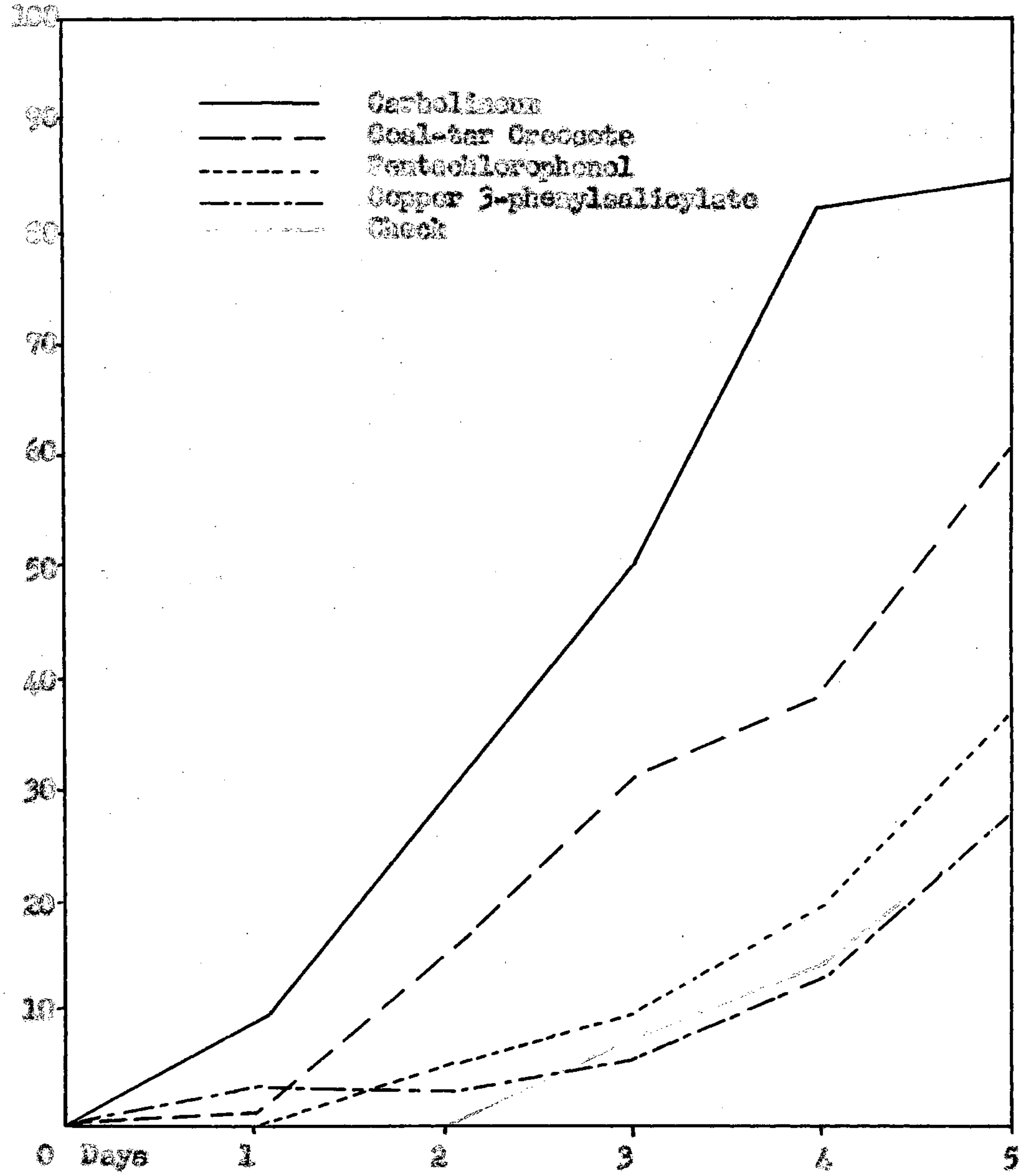
Table 15

Summary of Series VII and IX in Per Cent Mortality Caused by Fumigation when Test Bees were Caged in Special Double Screened Cages on Pine Panels Treated with Various Wood Preservatives and Air Dried One Day

Wood Preservative	Test Series	Per Cent Mortality by Days 1	2	3	4	5
Carbolineum	VII	10	23	40	67	70
	IX	10	37	63	97	100
	Average	10	30	51	82	85
Coal Tar Creosote	VII	3	3	10	10	37
	IX	0	30	53	67	87
	Average	1	16	31	38	62
Copper 3-Phenyl-salicylate	VII	3	3	3	10	20
	IX	3	3	10	17	37
	Average	3	3	6	13	28
Pentachlorophenol	VII	0	0	0	3	17
	IX	0	10	23	37	57
	Average	0	5	11	20	37
Check	VII	0	0	7	13	17
	IX	0	0	10	17	40
	Average	0	0	8	15	28

Figure 11.

Mortality Curves in Per Cent Dead Bees by Days When Caged in Special Double Screened Cages Which Prevented Bees Coming in Contact with the Treated Surface.



mortality rates of 28 and 37 per cent respectively. Figure 11 shows the mortality by days in per cent for the two fumigation series for each of the four preservatives and the check.

These tests indicate that preservatives which produce strong odors should be thoroughly air dried when used in treating beehive equipment. They also indicate that the fumes produced by coal-tar wood preserving products apparently have a detrimental effect on bees. Preservatives such as copper 3-phenylsalicylate and pentachlorophenol did not produce toxic fumes which were detrimental to the honeybee. These two chemicals caused mortality rates which were significant when test bees were caged in contact with wooden surfaces treated with them.

MISCELLANEOUS WOOD PROTECTANTS TESTED

Limited tests were made in Series X with wood protecting materials that have been used by beekeepers. These tests were to determine if any of these chemicals or treatments were toxic to the honeybee on contact. The following materials were tested in this series, white paint, "Kelley's Rot Proofing Compound," sodium pentachlorophenate, a mixture of asphalt and white gas, and a fifty-fifty mixture of coal-tar creosote and used crank case oil.

Discussion and Results: These tests were conducted in the same manner as those described for the other series. Results of the experiments are given in Table 16.

White paint for a number of years has been the standard protective material for beehives. The regular practice is to paint the outside of the beehive with two or three coats of the best grade of white paint. This protects the outside of the beehive from weathering and helps keep the inside of the hive cool during hot weather by reflecting the heat rays of the sun. However, white paint does not have a wood preserving additive to prevent decay and termite attack. Painted hives begin to decay at the corners after a few years use due to the high humidity of the hive which encourages wood-rot organisms. Two cage tests were made. The test panels were painted with one coat of a number one white paint manufactured by Davis Paint Company, Baltimore, Maryland. Test bees were caged against the treated surface after a one day air drying period. White paint was non-toxic to the test bees in these contact tests. When compared with the

Table 16

Per cent Dead Bees by Days When Caged Against Pine Panels Given a Five Minute Soak in Various Wood Protectants.

Wood Protectant	Days Air Dried	Per cent Dead Bees in Cages by Days 1	2	3	4	5	6	7
White paint	1	0	0	5	10	10		
	1	0	0	0	0	0	0	0
Kelley's Rot Proofing Compound	1	5	5	5	5	15		
	1	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0
	1	0	0	0	0	10	10	10
5% Sodium Pentachlorophenate	1	0	0	40	95	95		
	1	0	0	0	10	60	80	100
	1	0	0	10	30	50	80	
	1	0	0	10	40	80	100	
	7	0	0	10	40	90	100	
	7	0	10	10	100			
	28	0	0	0	0	0	0	0
10% Asphalt	1	0	0	0	0	5		
20% Asphalt	1	0	0	0	0	0	0	0
50% Coal-tar Creosote and 50% Crank Case Oil	1	0	0	0	10	30		
	1	0	0	0	10	10	10	30
	1	20	90	100				
	1	0	80	100				
	7	0	70	90	100			
Check		0	0	0	0	10	10	10

untreated check, at the end of the test period, the mortality was less than that of the check, being 5 per cent with the check 10 per cent.

"Kelley's Rot Proofing Compound" is a commercial product sold by the Walter T. Kelley Company, manufacturer of beekeeping supplies. This material is sold to beekeepers as a concentrate for hive preservation. The active ingredients are not known by the writer. Kelley recommends for a dip treatment one part of concentrate to five parts organic solvent such as mineral spirits. The concentrate is a tan viscous material that imparts a light color to the preserving solution. It is odorless, non-staining and apparently non-irritating and non-caustic. It did not stain the test panels and after drying was not detected on the wood. Four cage tests were made with this product. All tests were air dried for one day. This material was found non-toxic to the test bees. At the end of the test period the mortality rates of bees caged against panels treated with this material were equal to the checks.

Sodium pentachlorophenate was used as a five per cent aqueous solution in these tests. Sodium pentachlorophenate is one of the water soluble salts of pentachlorophenol. It is widely used in the lumber industry for the control of blue stain and other molds which attack lumber while air drying. The product used in these tests was manufactured by the Dow Chemical Company of Midland, Michigan, and is sold under the trade name of "Dowicide G." The powder is readily soluble in water. This material was included in these tests because water solutions are considerably less expensive than oil solutions. Sodium pentachlorophenate is very irritating to the eyes and nose, and disagreeable to mix and use. However, it is considered relatively non-toxic to humans. Like pentachlorophenol, it may cause dermatitis on some individuals.

The test panels were given a five minute soak in the solution and given three different air drying periods. These were one day, seven days and twenty-eight days. After drying the panels were covered with a coating of fine crystals of the salt. Sodium pentachlorophenate was highly toxic to the test bees after the one and seven day airing periods. For these two tests mortality rates were approximately 100 per cent at the end of the test period. After twenty-eight days air drying, the mortality rate was equal to the check. Sodium pentachlorophenate at a five per cent solution is apparently more toxic to the honeybee than a five per cent solution of pentachlorophenol in oil. It is doubtful if this material should be used for treating beehive equipment.

Hot asphalt has been suggested by beekeepers as a treatment for bottom boards of beehives. In these experiments a ten and a twenty per cent solution of asphalt in white gasoline was used as a cold dip in place of hot asphalt. This is a very cheap treatment, but has the disadvantage of leaving a sticky coating of black asphalt over the surface of the treated wood. The asphalt has a tendency to soften during hot weather, and when moving hives during the summer would be very disagreeable. The asphalt treatment as used in these tests was non-toxic to the test bees. Mortality rates for both dilutions were equal to the check.

A mixture of fifty per cent coal-tar creosote and fifty per cent used crank case oil has been used by Florida beekeepers for treating bottom boards. For this reason five cage tests were made with this mixture. After a five minute soak in a mixture of this nature the treated panels were very greasy and had a strong creosote odor. The odor was present after seven days air drying. The test panels were air dried for one and seven days. Mortality rates were high in three of the five tests. After seven days airing the mortality rate was 100 per cent after four days exposure. The mortality rates for bees caged against wooden surfaces treated with the coal-tar creosote and crankcase oil mixture were comparable with those of creosote diluted with fuel oil.

EFFECTS OF VARIOUS SOLVENTS ON THE HONEYBEE

Many wood preservating materials can be bought in a concentrated form to be diluted with locally obtained solvents at the time the wood is to be treated. By purchasing the concentrated material the user saves on freight and container costs. In some instances the cost of the preservative may be reduced by half. In using the concentrate it is necessary to obtain a solvent that will dissolve the preservative and also have good penetrating properties into wood. The beekeeper needs in addition a solvent that is readily volatile to prevent injury to the hive bees. Since most good preserving materials are insoluble in water but readily soluble in the aliphatic oils and aromatic hydrocarbons several of these compounds were included in the test.

This study was made to determine what effect the various solvents had on caged honeybees.

Discussion and Results: Ten solvents and a check were included in these tests. They were mineral spirits, fuel oil, carbon tetrachloride, acetone, turpentine, white gasoline, xylene, isopropyl alcohol, amyl acetate, and kerosene. The tests were handled in the same manner as previously described. The test panels were given a five minute soak, and then air dried for twenty-four hours. Test bees were then caged against the treated surfaces and observed for a seven day period. The panels were randomized to prevent any possible build up of fumes which could effect the results.

A summary of the mortality rates by days is presented in Table 17. These data indicate that solvents which are readily volatile were less toxic to the test bees than those which volatilized slowly. Materials such as mineral spirits, carbon tetrachloride, acetone, white gasoline, amyl acetate, xylene, and isopropyl alchol caused less mortality than the slowly volatile compounds which remained longer on the surface of the wood. Kerosene and fuel oil caused higher mortalities than the other chemicals, the rates being 53 and 37 per cent respectively. Turpentine, which retained a strong odor for several days, caused a mortality rate of 27 per cent. Isopropyl alcohol caused a mortality of 10 per cent at the end of the first day and 27 per cent at the end of seven days. The 10 per cent mortality on the first day was probably due to injured bees, since all dead bees were in the same cage.

Records were kept on the amount of honey-candy consumed by the test bees during the exposure period. There apparently is a relationship between the amount of food consumed and the rate of volatility of the solvent. Solvents such as fuel oil, and kerosene apparently had a narcotizing effect on the test bees, because they showed less activity than the other caged bees and consumed less food. Cages which had the least mortality consumed the most food, and the bees were active throughout the test period. Bees caged against a panel treated with xylene were stupified by the vapors of the chemical at the end of the second day. They remained on the bottom of the cage and moved their legs and antennae very slowly. On the third day they were more active and eight of the ten bees returned to normal by the fourth day. These symptoms are typical responses of high vapor concentrations of xylene, benzene and related compounds.

Table 17

A summary in per cent dead bees by days when caged against pine panels given a five minute soak in various solvents and air dried for twenty-four hours before exposure.

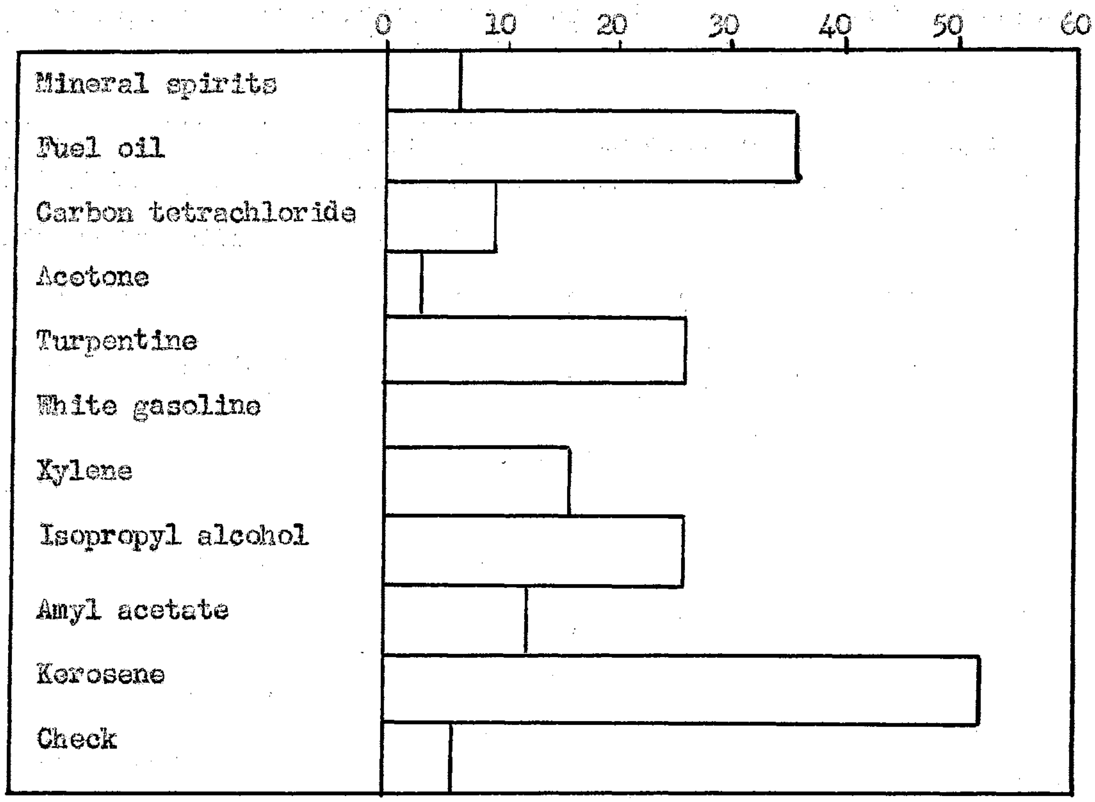
Solvent Tested	Per cent Mortality by Days 1	2	3	4	5	6	7
Mineral spirits	0	0	3	3	3	7	7
Fuel oil	3	3	7	10	13	23	37
Carbon tetrachloride	0	3	7	7	10	10	10
Acetone	0	0	0	0	3	3	3
Turpentine	0	0	0	13	23	27	27
White gasoline	0	0	0	0	0	0	0
Xylene	7	7	7	13	17	17	17
Isopropyl alcohol	10	10	20	20	27	27	27
Amyl acetate	0	0	0	3	3	7	13
Kerosene	6	27	27	30	43	50	53
Check	0	3	3	3	7	7	7

No solvent tested was considered highly toxic to the test bees. The highest mortality occurred near the end of the exposure period. Highly toxic materials should have produced high mortalities on the first and second days. The data in Table 13 shows little or no mortality occurring during the first three days of the test. These data indicate that all ten solvents are safe for diluting wood preservative concentrates for beehive treatment, provided a sufficient airing period is allowed for volatilization. Kerosene and fuel oil should be air dried longer than the other solvents tested.

Figure 12 shows the per cent mortality after seven days exposure to panels dipped in various solvents and air dried for twenty-four hours.

Figure 12

Per cent Mortality after Seven Days Exposure to Test Panels Dipped in Various Solvents and Air Dried Twenty-four Hours.



THE EFFECTS OF HUMIDITY AND TEMPERATURE ON THE TEST PANELS

Temperature and humidity records were kept during the periods the test panels were air drying. This was done to determine if variations in temperature and humidity would have any effect on the removal of volatile substances from the treated wood. After the five minute soak treatment the test panels were thoroughly wet with the preserving chemical. During periods of dampness it was noted that some panels remained wet looking for several days. Due to the failure of the recorder on certain days, complete records are not available for all of the air drying periods. In Table 18 will be found a summary of the humidity and temperature data for Series II and III. These data are for a seven day air drying period and give the per cent relative humidity and temperature as to high, low and average for each day with an average for the seven day period. These data show that the air drying period for Series II was during a period of relatively high humidity, with the average per cent relative humidity for the period 73.7 per cent. The air drying period for Series III is considerably lower with an over all average of 65.0 per cent relative humidity. This difference in humidity is apparently reflected in the mortality rates of the test panels for the two series. Series II had a mortality rate for all nine preservatives of 55.7 per cent and Series III had a total 41.7 per cent. Table 19 presents a summary of the mortality rates in per cent for the two series by days for the different wood preservatives tested. This table shows that six of the nine chemicals tested caused higher mortality

Table 18

Humidity and Temperature Records by Days During the Seven Day Air Drying Period for Series II and III.

Series II		October - 1950 6	7	8	9	10	11	12	13	Average
	High	82	82	88	91	83	84	--	--*	
Humidity	Low	63	60	58	80	40	40	--	--	
	Average	76.2	73.2	76.1	84.9	60.3	71.5	--	--	73.7
	High	75	82	83	76	80	82	83	79	
Temperature	Low	64	66	70	70	60	58	56	59	
	Average	68.2	73.5	75.2	72.9	68.9	68.6	68.9	68.2	70.6
Series III		**April - 1952 19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**Average**
	High	80	80	77	80	80	78	84	86	
Humidity	Low	36	48	46	34	45	54	51	53	
	Average	57.4	61.2	61.8	59.5	63.2	73.2	71.2	72.7	65.0
	High	78	74	78	83	84	78	81	77	
Temperature	Low	52	57	60	62	62	66	68	65	
	Average	65.0	67.2	69.2	72.3	72.1	71.1	72.1	69.1	69.8

*Recorder failed to record humidity during these days.

Table 19

A Comparison of Mortality Rates of Series II and III by days Using data from Test Panels Given Seven Days Air Drying.

Preservative Used	Series Number	Per Cent Mortality by Days 1	2	3	4	5	6	7
Carbolineum	II	0	0	47	60	73	73	90
	III	0	7	53	80	87	97	100
Celcure	II	0	0	0	0	10	13	27
	III	0	0	13	17	17	27	33
Chromated Zinc Chloride	II	0	0	0	10	17	37	50
	III	0	0	3	7	10	10	23
Coal Tar Creosote	II	53	73	77	80	87	90	90
	III	3	10	17	37	50	63	70
Copper 3-Phenyl-salicylate	II	33	33	33	33	37	43	47
	III	0	0	3	10	13	17	23
Copper Naphthenate	II	3	33	33	33	40	53	70
	III	0	0	3	17	23	33	33
<u>Cuprinol</u> # 70	II	23	33	33	37	40	43	50
	III	0	0	3	10	13	13	13
Pentachlorophenol	II	0	3	7	23	47	57	67
	III	0	0	0	7	17	27	40
Zinc Naphthenate	II	0	0	0	0	0	7	10
	III	0	0	0	3	23	37	40

rates on panels air dried during a period of high humidity than on panels that were air dried during a period of low humidity. The preservatives that caused higher mortality to bees on the panels air dried during the period of high humidity, with the increase in per cent, were as follows: chromated zinc chloride, 27; coal-tar creosote, 20; copper 3-phenyl-salicylate, 24; copper naphthenate, 37; "cuprinol No. 70," 27; and pentachlorophenol, 27. Although the data indicates three materials to cause less mortality on panels dried during a period of high humidity, the writer cannot account for this difference. It is interesting to note, that with the exception of zinc naphthenate, the differences in mortality of these preservatives were small. They were ten per cent for carbolineum, six per cent for "celcure," and thirty per cent for zinc naphthenate.

The average temperature for these two periods was relatively the same. In Series II the average temperature for the seven day period was 70.6° F., and in Series III it averaged 69.8° F. Although there is a difference of eight-tenths of a degree F. it is interesting to note that in Series III with the lower mortality, the temperature and relative humidity were also the lower of the two series.

COST OF TREATING BEEHIVE EQUIPMENT

In making an economic study of the use of wood preservatives for treating beekeeping equipment, the cost of treating the various hive parts should be taken into consideration. Wood preservatives vary in cost and in their ability to penetrate wood materials. Preservatives with greater penetrating power give longer protection and require larger quantities of the chemical to treat a given piece of equipment. Since beekeeping is an agricultural industry which must keep operating costs to a minimum in order to show a satisfactory profit to the beekeeper, the preservative cost for treating the hive parts is of considerable importance.

In all experiments in this study a standard five-minute dip in the preservative was given to all test panels and all pieces of equipment treated. A dip treatment of this length of time allows sufficient time for the preservative to enter the cracks and joints of the hive parts and in addition fits satisfactorily into the beekeeper's assembly program. Most hive parts are mass produced in the beekeeper's wood working shop, or obtained from one of the bee supply houses in a knock-down condition. The assembly work of putting together and nailing the various precut boards is usually done at one time of the year. In working out a wood preservation program for the beekeeper, the treatment of the wooden parts should take a minimum of time and fit easily into the assembly program. Since it requires approximately five minutes to assemble and nail a unit of beehive equipment, a five-minute soak or dip in the preservative would fit easily into the assembly program. As one piece of equipment was completed it could be dropped into the wood preservative tank where it could remain until the next unit was constructed, at which time it could be removed and allowed to drain while the second unit soaked. With this kind of a program in mind, a series of tests were conducted to determine the unit cost of treating various hive parts with a five-minute soak for eight different wood preservatives.

Equipment and Materials

Equipment: A special galvanized tank was constructed for use in these tests. This tank had inside measurements of twenty-four inches for length, nineteen and one-fourth inches for width, and fourteen inches for depth. It was made out of 16-gauge galvanized iron and had a lip extending out around the top one and one-half inches wide. A tank of this size accommodated easily the various pieces of a standard Langstroth bee-hive. The tank was made this size so that one gallon of preservative would fill the tank to a depth of exactly one-half inch. This made possible a simple method of measuring the amount of preservative which would be soaked up by the hive parts. A three-quarter inch pipe nipple was welded into one end of the tank at the bottom, into which was screwed a faucet for draining the preservatives. A cover was made out of the same gauge galvanized iron and measured twenty-three by twenty-seven inches. Three sides of the cover were turned up for three-fourths of an inch. The cover was made to fit snugly against the lip of the tank. When the tank was not in use the cover prevented the rapid evaporation of the solvent, and when the tank was in use it acted as a drainboard. A tank of this general size and construction would be satisfactory for use on a commercial bee farm.

Hive Parts Treated: Four kinds of beekeeping equipment were included in these tests. They were deep supers, shallow supers, bottom boards and solid wood covers. The hive parts were constructed of three kinds of wood: cypress, southern yellow pine, and western pine. All hive parts treated were the standard Langstroth size.

Preservatives Used: Eight preservatives were used in these tests. They were, carbolineum, "celcure," a ten per cent aqueous solution of chromated zinc chloride, copper naphthenate (cuprinol #10), "cuprinol #70," "Kelley's Rot Proofing Compound" diluted one to five in mineral spirits, five per cent pentachlorophenol ("Permatox WR") and 3.2 per cent zinc naphthenate in mineral spirits. The chromated zinc chloride and "celcure" were water solutions. All other preservatives were oil solutions.

Methods

Code letters were assigned to each preservative and before treatment the hive parts were marked on the inside with a metal die. This was done to prevent any mix-up in the number of parts to be treated, and also to make possible a study at a later date as to the effectiveness of the various preservatives when used under actual beekeeping conditions. The preservative tank was thoroughly washed with mineral spirits and placed on a firm stand. The cover was placed on one side to be used as a drainboard (See Plate 6). The wood preservative was poured into the tank and measured as to depth with a steel ruler graduated in thirty seconds of an inch. All measurements were made in the right hand corner. Three measurements were taken in order to determine the exact amount of preservative in the tank. The depth was recorded on a data sheet. The hive parts were

Plate 6.

Dipping shallow supers in the special dipping tank filled with wood preservative. Note the tank cover being used as a drain board.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placed in the tank and allowed to soak for five minutes. With some types of hive equipment the hive parts were placed in the preservative and continually turned over and over until the end of the five-minute period. This made possible more rapid treatment in this size tank, and also the use of smaller amounts of the test preservatives, as it was not necessary to fill the tank. At the end of the five-minute soak, the hive parts were placed on the drain where they remained for five to ten minutes. After draining the treated hive parts were stacked and allowed to air dry before use on the hives (See Plate 7). When the last hive part had finished draining, and the preservative had settled, the depth of the preservative was measured and recorded. The difference in the depth of the preservative determined the amount that had soaked into the wood. With preservatives such as pentachlorophenol, copper naphthenate, and carbolineum, synthetic rubber gloves were used to prevent the preservative coming in contact with the operator's hands. The tank was thoroughly cleaned with mineral spirits or water, depending on the type of preservative, before another preservative was placed in the tank. In all dipping tests five or ten hive parts were treated before the depth of the solution was measured.

Observation and Discussion

In these tests to determine the amount of material required to treat the various hive parts, two hundred and fifty-five units were treated. They consisted of forty deep supers, one hundred and sixty shallow supers, forty-five bottom boards and ten wood covers. The number treated with each preservative is given in Table 20. Carbolineum was used only on bottom boards because of the toxic nature of the material and the dark

Plate 7

One hundred and thirty-three shallow supers and twenty bottom boards air drying after a five-minute dip treatment with various wood preservatives before use on beehives.

Table 20

The Number and Type of Hive Parts Given a Five-Minute Soak in Various Wood Preservatives to Determine the Unit Cost.

Wood Preservative Used	Deep Supers	Shallow Supers	Bottom Boards	Wood Covers
Carbolineum	-	-	5	-
Celcure	5	30	5	-
Chromated Zinc Chloride 10%	-	30	5	-
Copper Naphthenate (Cuprinol #10)	5	30	5	-
Cuprinol #70	10	5	5	-
Kelley's Rot Proofing Compound	5	10	-	-
Pentachlorophenol 5%	10	50	15	10
Zinc Naphthenate	5	5	5	-
Total	40	160	45	10

color imparted to the wood. No attempt was made to treat the same number of hive parts with each preservative. More hive parts were treated with 5 per cent pentachlorophenol because this is an effective material and the most economical of the oil soluble preservatives tested.

Amount of Preservative Used: The amount of preservative required to treat the various hive parts is given for each of the eight materials in Table 21. The oil solutions as a rule penetrated more into the wooden hive parts than did the water solutions. A steady stream of small bubbles was noticed coming from the corners of a super being dipped during the first two or three minutes it was held under the oil type preservative. This was not noticed when the treatment was made with the aqueous solutions. Although these tests are only approximate due to the variations in the kinds of wood and different amounts of heart and sap wood in the hive part, the data obtained are helpful in determining the amount of preservative required to treat the various hive parts. Preservatives have a tendency to penetrate sap wood readily, but little or no penetration is made into seasoned heart wood. Soft woods like pine take up more of the preservative than the harder close grain woods such as cypress. In these tests copper naphthenate required more preservative to treat a given hive part than any of the other preservatives tested. An average of eleven and two-tenths ounces of copper naphthenate was soaked up by a deep super, while only three and two-tenths ounces of "celcure" were soaked up by the same type equipment. A bottom board required 9.6 ounces of carbolineum and copper naphthenate for treatment, with only 3.2 ounces of chromated zinc chloride being required. The bottom boards treated with carbolineum had much of the chemical adhering to the surface of the lumber, and required approximately 24 hours to dry. The copper naphthenate treated bottom board had little of the solution on the surface of the wood,

Table 21

The Average Amount of Wood Preservative in Ounces Required to Treat Ten Hive Parts for a Five-Minute Soak for Eight Wood Preservatives

Preservative Used	Type of Hive Parts Treated			
	Deep Supers	Shallow Supers	Bottoms	Covers
Carbolineum	—	—	96	—
Celcure	32	21	64	—
Chromated zinc chloride	—	16	32	—
Copper naphthenate	112	43	96	—
Cuprinol Number 70	32	32	80	—
Kelley's rot proofing compound	80	32	—	—
Pentachlorophenol	96	37	80	32
Zinc naphthenate	96	48	64	—

and was generally dry to touch in less than an hour. With few exceptions it required approximately twice the amount of preservative to treat a deep super as it did a shallow super. The amount used in treating a bottom board was slightly less than that needed for a deep super. This is in direct relation to the surface area of the hive parts. The writer cannot account for deep supers and shallow supers requiring the same amount of "cuprinol #70" for treatment. The only difference was the deep supers were made of western pine and the shallow supers were made of southern yellow pine. The difference in these two woods should not account for this variation in the data. The number of supers available for treatment was limited, therefore the test was not repeated. As previously mentioned the amounts of preservative required are approximate, and should be used only as a guide.

Cost of Preservatives Used: The cost of the preservatives used in these tests varied from twenty cents a gallon for the ten per cent chromated zinc chloride solution to that of four dollars and seventy cents a gallon for the cuprinol products. The costs per gallon of the eight preservatives were obtained from the manufacturers during the last part of 1952. Chemical compounds fluctuate in price, and the prices given in Table 22 should be used as a comparison or guide only. There is a variation in the price of wood preservatives based on quantity purchases. For this reason the prices of both small quantities and barrels were computed in this study. Many preservatives can be obtained as a concentrate to be diluted by the user. There is a considerable difference in the price of the ready-to-use preservative and the diluted concentrate. In the case of pentachlorophenol in barrel lots the cost of the diluted concentrate was less than half of the ready-to-use material. Copper naphthenate can also be obtained as a concentrate and when diluted cost approximately

Table 22

The Cost in Cents of Treating One Hive Part with a Five-Minute Soak for Eight Different Wood Preservatives.

Preservative Used	Quantity Price per Gallon	Deep Supers	Shallow Supers	Bottom Boards	Wood Covers
Carbolineum	5[1] - $1.95	—	—	14.62	—
	55 - 1.45	—	—	10.88	—
Calcure	5 - 1.60	4.00	2.62	8.00	—
	55 - 1.05	2.63	1.72	5.25	—
10% Chromated Zinc Chloride	60 - 0.20	—	0.25	0.50	—
Copper Naphthenate (Cuprinol #10)	1 - 4.70	41.13	15.79	35.25	—
	55 - 4.20	36.75	14.11	31.50	—
Cuprinol #70	1 - 4.70	11.75	11.75	29.38	—
	55 - 4.20	10.50	10.50	26.25	—
Kelley's Rot Proofing Compound	5 - 0.75	4.69	1.87	—	—
	55 - 0.50	3.13	1.25	—	—
Pentachlorophenol	5[2] - 1.31	9.82	3.78	8.18	3.27
	55 - 1.13	8.48	3.27	7.04	2.83
	5[3] - 0.60	4.50	1.74	3.75	1.50
	55 - 0.55	4.13	1.59	3.44	1.38
Zinc Naphthenate	5 - 1.00	7.50	3.75	5.00	—
	55 - 0.80	6.00	3.00	4.00	—

[1] Price per gallon when bought in five or fifty-five gallon containers.

[2] Price per gallon of the ready-to-use commercial product.

[3] Price per gallon of pentachlorophenol concentrate diluted with mineral spirits.

half that of the prepared material.

The cost of treating the various hive parts varied for bottom boards from 35.25 cents each for copper naphthenate (cuprinol #10) to only 0.5 of a cent for 10 per cent chromated zinc chloride. Cost variations similar to this were found for the other hive parts treated. The unit cost for the different hive parts treated by the eight preservatives is given in Table 22. Price alone is not a satisfactory criterion for selecting a wood preservative for beehive treatment. Such things as toxicity, color, odor, corrosiveness and maximum protection must be taken into consideration. The eight preservatives can be grouped according to cost. Such a grouping would place copper naphthenate (cuprinol #10 and #70), as very expensive preservatives; carbolineum, "celcure" and the ready-to-use pentachlorophenol is a group of medium priced materials; and chromated zinc chloride, "Kelley's Rot Proofing Compound," zinc naphthenate and diluted pentachlorophenol concentrate as low priced preservatives. From an economical point of view a preservative which cost over five to ten cents per unit treated is too expensive for the beekeeper, since satisfactory materials are available within this price range.

SOIL CONTACT TESTS

This study of the toxicity of the various wood preservatives to the honeybee and the cost of treating the different beehive parts were both based on a five-minute dip treatment. It is recognized that a treatment for a longer time would be more effective due to the greater penetration of the wood preservative into the wood; however, a longer treating period would not fit as satisfactorily into a beekeeper's hive construction routine as well as the five-minute soak. Since beehives are continually exposed to weathering and many times to soil contact, a thorough study of wood preservatives for beehive treatment should include field exposure tests to determine the effectiveness of the proposed treatment.

In this study, accelerated stake tests were used to evaluate the effectiveness of a dip treatment of this nature for the preservatives tested as to their resistance to wood rots and termite attack.

Methods

In May, 1950, a field exposure experiment was begun to test eight different wood preservatives as to their effectiveness in preventing fungous decay and termite attack to pine panels given a five-minute soak treatment. The experiment consisted of three series of 27 panels each, in which the eight preservatives and a check were replicated three times. The preservatives tested were carbolineum, "celcure," chromated zinc chloride, coal-tar creosote, copper naphthenate, "Cuprinol #70," pentachlorophenol, and zinc naphthenate. The test panels were numbered according to a randomized design.

The treated panels were exposed to soil contact and weathering conditions in a termite infested woods on the campus of the University of Florida. This area was first tested for the presence of termites by scattering pieces of boards over the ground and examining them two to four weeks later. At the time of examination many of the boards were infested with termites which indicated the presence of many termite colonies in the area. Approximately twenty feet from the exposure area was a small stream. The ground remained moist most of the time and the humidity was usually high. Trees shaded the area and within a few months time grass and leaves covered the panels.

At the time of placing the panels in contact with the ground, the grass and leaves were removed from three strips six inches wide and eight feet long. The panels were placed in these strips two to three inches apart according to the randomized design with one end in contact with the soil. A wire was placed over the top of the panels and fastened to each panel with a staple three-fourths of an inch long. The driving of the staple in the top of the panel helped force it into the ground. At the end of the rows of panels an untreated two by two inch stake was driven into the ground to which the ends of the wire were fastened. The wire held the panels in place during the exposure period. The panels were not disturbed or examined during the thirty months exposure period.

During November, 1952, the end stakes were removed and the wires containing the test panels were taken to the laboratory for examination. The panels were examined for both wood rots and termite attack. For recording the data, the panels were divided into four parts. At the time of treatment the end to which the number was fastened was not dipped in the preservative, therefore, only the bottom three-fourths of the panel was treated with the preservative. The treated area was divided into three parts, that which was in contact and below the soil surface, the middle third of the treated area, and the top third of the treated area. The fourth part was the top of the panel which was untreated. The four parts were lettered A, B, C, and D respectively. Data sheets were prepared so the injuries by decay and termites could be recorded for each of the four areas. At the time of examination only the experimental numbers were present on the panels and the treatments were unknown. After all the panels of the three series had been examined the treatments were recorded and the results compared.

Observation and Discussion

When the test panels were removed from the termite infested area three of the end stakes had been completely riddled by termites and easily broke off at the ground level. The remaining stake was infested and half consumed by termites. A number of the test panels were hollow shells, having been almost completely consumed by termites. Table 23 summarizes the injury by decay and termite attack for the three series by chemicals. The effects of the thirty months exposure on the panels will be discussed separately for each of the preservatives in the test.

<u>Carbolineum</u>: At first examination the panels which were treated with carbolineum appeared to be well preserved. Two of the panels showed outwards signs of decay at A or the ground level. However, upon closer examination many of the panels showed signs of decay and termite attack. Only

Table 23

The Effects of 30 Months Exposure on Pine Panels which had been Given a Five-Minute Soak in Various Wood Preservatives and Placed in Contact with Sandy Soil in a Termite Infested Area. Injury in per cent Damage[1]

Chemical Used	Series No.	Injury by Decay A	B	C	D	Injury by Termite A	B	C	D	Total Damage
Carbolineum	I	37	0	0	8	17	17	17	17	28
	II	42	7	0	15	0	0	0	0	16
	III	17	7	3	15	25	17	8	0	23
	Average	32	5	1	13	14	11	8	5	22
Celcure	I	67	22	7	12	32	30	30	27	57
	II	42	17	0	10	5	0	3	8	21
	III	13	3	0	5	10	8	7	3	12
	Average	41	14	2	9	16	13	13	13	30
Chromated Zinc Chloride	I	66	3	0	8	33	15	0	0	31
	II	0[2]	0	0	3	63	7	8	33	29
	III	25	8	7	17	25	20	17	13	33
	Average	30	4	2	9	40	14	8	15	31
Coal-tar Creosote	I	27	0	0	12	0	0	0	0	10
	II	33	13	5	13	7	7	7	8	23
	III	2	0	0	2	0	0	0	0	1
	Average	21	4	2	11	2	2	2	3	12
Copper Naphthenate	I	0	0	0	2	0	0	0	0	0.5
	II	0	0	0	3	0	0	0	0	1
	III	0	0	0	0	0	0	0	0	0
	Average	0	0	0	2	0	0	0	0	0.5

Table 23 (Continued)

Chemical Used	Series No.	Injury by Decay A	B	C	D	Injury by Termite A	B	C	D	Total Damage
	I	83	7	0	7	17	8	0	0	30
Cuprinol #70	II	38	0	0	5	0	0	0	0	10
	III	18	7	3	3	0	0	0	0	8
	Average	46	5	1	5	6	3	0	0	16
	I	12	0	0	5	3	0	0	0	5
Pentachlorophenol	II	12	0	0	0	5	0	0	0	4
	III	2	0	0	0	3	0	0	0	1
	Average	9	0	0	2	4	0	0	0	4
	I	0	0	0	0	0	0	0	0	0
Zinc Naphthenate	II	0	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0	0
	Average	0	0	0	0	0	0	0	0	0
	I	0[2]	0	0	7	100	96	85	77	91
Check	II	0	0	0	0	100	100	80	75	89
	III	0	0	0	0	100	72	63	57	73
	Average	0	0	0	4	100	88	78	70	85

System of recording data: A - Bottom third of treated panel.
B - Middle third of treated panel.
C - Top third of treated panel.
D - Untreated top of panel.

[1]Test panels were divided into four parts for recording injury.

[2]Area destroyed by termites and no record of injury by decay could be made.

two of the nine panels were found free of injury in the preservative treated area. Three had inside damage caused by termites. Two of the panels showed signs where termites had attempted to enter, but apparently were unable to get through the treated surface. Six of the panels were soft in areas A and B, indicating fungus penetration. For the three series, Area A showed an average of 32 per cent injured by decay and 14 per cent by termites. The over-all damage to the carbolineum treated panels was an average of 21 per cent. When compared with the check, which averaged 85 per cent of all panels damaged, carbolineum showed some wood preserving properties; however, five of the eight wood preservatives tested had less damage. Plate 8 shows two views of the nine exposed panels treated with this chemical under the letter A. The middle picture shows the panels cut through the middle. The amount of penetration of the carbolineum into the wood can be seen by the dark areas.

Celcure: Three of the panels treated with "celcure" were infested with termites at the time of examination. Two of these were completely riddled and one was infested in areas A and B. Six of the panels were rotten in Area A. The water soluble salts of the "celcure" treatment apparently leached out through contact with the soil. Three of the panels showed no injury to the area treated with the chemical. The average over-all damage to all panels was 30 per cent. That section of the panels in contact with the soil had a combined injury by decay and termites of 57 per cent. The condition of the treated panels is shown in Plate 8 under B. Only one preservative had a higher per cent injury than "celcure," and that by only one per cent. The dip treatment with "celcure" in these tests was not satisfactory.

Chromated zinc chloride: All nine of the panels treated with Chromated

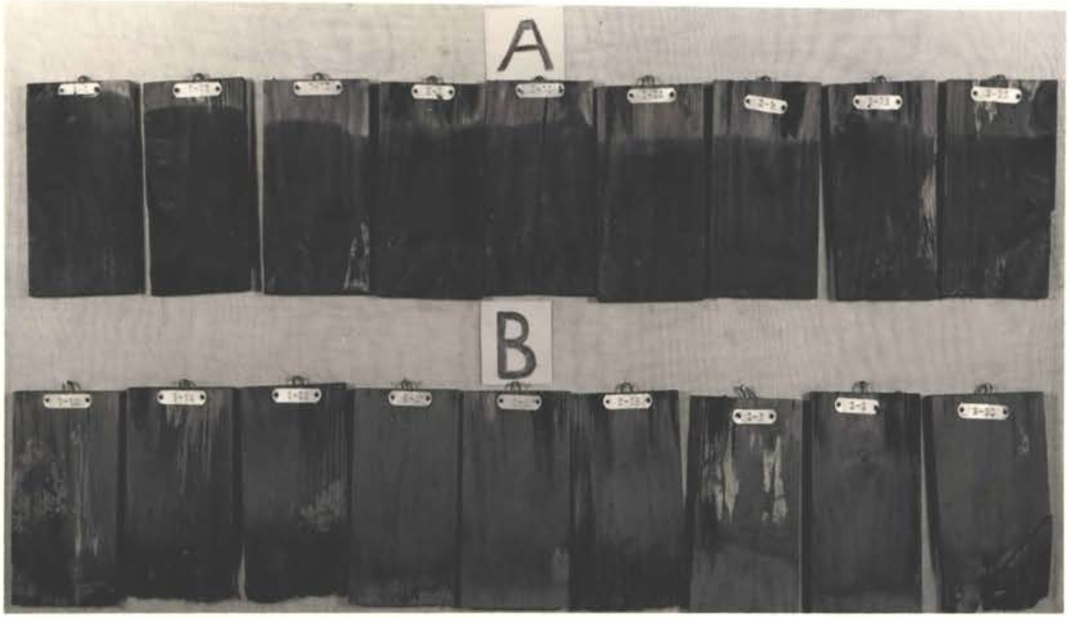
Plate 8.

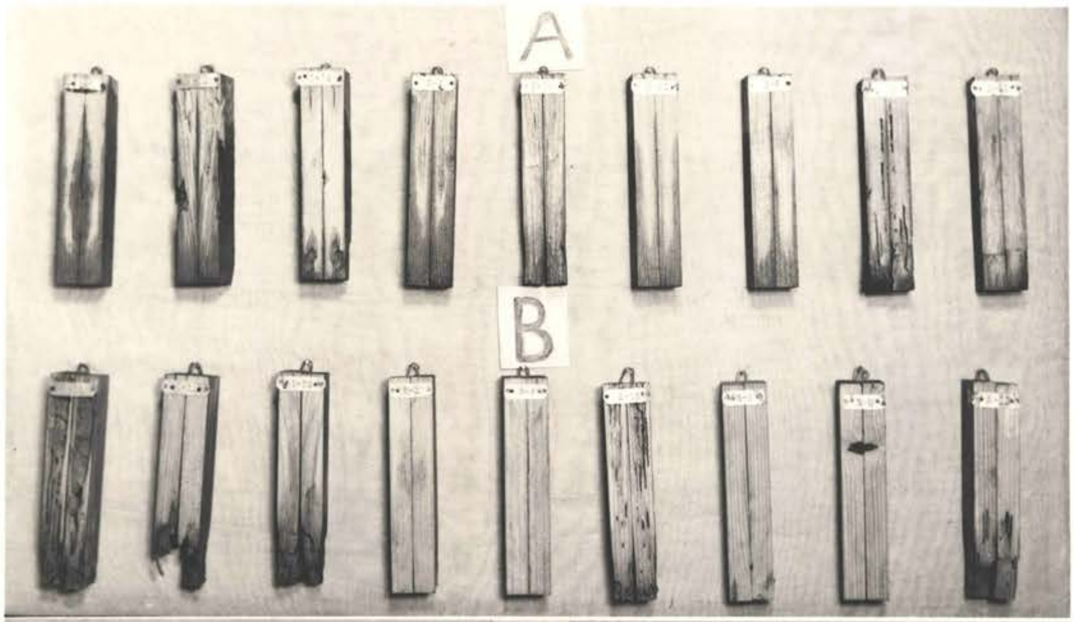
Test panels which had been given a five-minute soak in a wood preservative and exposed for thirty months in a termite infested area.

A - treated with carbolineum

B - treated with "celcure"

J - untreated check


A
B


A
B


J

zinc chloride were damaged. Seven were infested with termites and two were injured by decay. The injury was more severe in the area in contact with the soil. An average of 70 per cent of this area was destroyed. Three panels were riddled by termites from top to bottom. This material had the highest percentage of damage of the preservatives tested. The over-all damage was 31 per cent for all panels in the three series. Chromated zinc chloride, like "celcure" showed signs of leaching of the preserving salts at the ground level. A five-minute dip treatment with water soluble preservatives was not satisfactory for wood placed in contact with the ground. The injury to these test panels is shown in Plate 9 under C.

Coal-tar Creosote: The exposed panels treated with coal-tar creosote were similar to those treated with carbolineum with little or no surface injury. However, seven of the nine panels were soft from decay in the area which had been in contact with the soil. One panel was attacked by termites which had eaten out a section of the center. Two of the panels were apparently free from injury. A summary of the decay damage for the three series for the area in contact with the soil was 21 per cent. The total damage to all panels was 12 per cent. The injury to the coal-tar creosote treated panels is shown in Plate 9 under D.

Copper Naphthenate: With the exception of the small amount of decay (0.5 per cent) found on the untreated top of the panels, those treated with copper naphthenate were in excellent condition. There was no visible evidence of decay or insect attack to the treated surface. The bright green color on the surface of the wood had faded, but when the panels were sawed through the middle, there was a faint green color throughout. Penetration into the wood was excellent. Plate 10 shows the copper naphthenate treated panels under F.

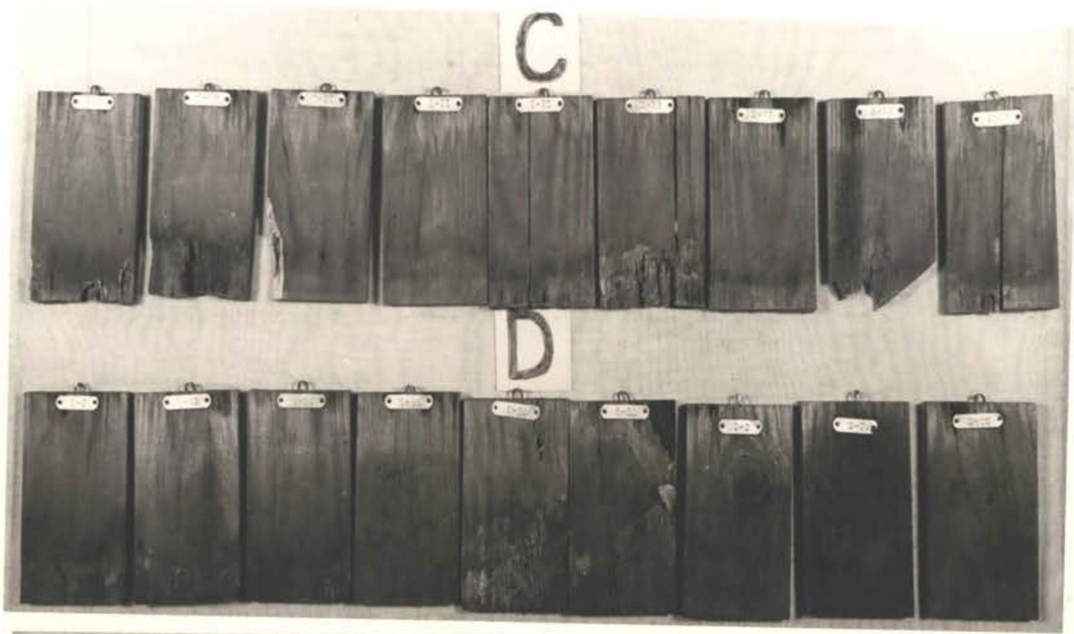
Plate 9.

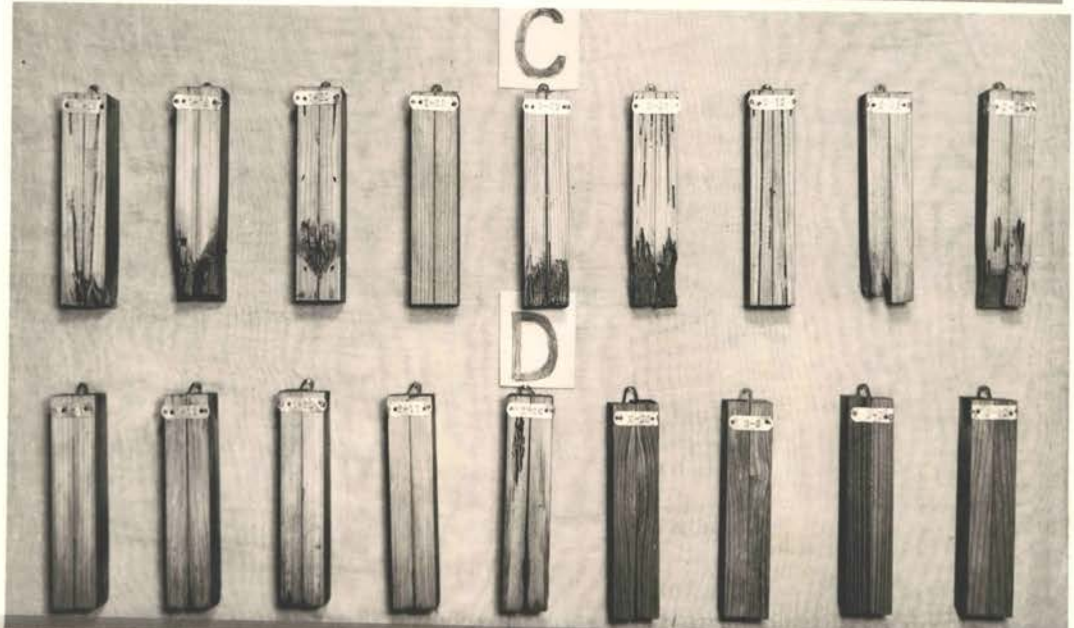
Test panels which had been given a five-minute soak in a wood preservative and exposed for thirty months in a termite infested area.

C - treated with Chromated zinc chloride

D - treated with Coal-tar creosote

J - untreated check


C
D


C
D


J

"Cuprinol #70": This material, which is a brown stain containing copper naphthenate, was not satisfactory in preserving the part of the test panel that came in contact with the soil. Seven of the test panels were soft from decay in the area that was touching the soil. One panel was infested with termites. Two panels showed no injury. For the three series, 52 per cent of area A was destroyed with an over-all damage to all panels of 16 per cent. "Cuprinol #70," which sells for the same price per gallon as copper naphthenate, did not give the same degree of protection. The injury to these test panels is shown in Plate 10 under G.

Pentachlorophenol: The panels treated with pentachlorophenol were in good condition with the exception of a small amount of the outer surface which was in contact with the soil. On six of the test panels there was evidence of termites feeding on the surface, but they were unable to enter the wood. The over-all damage to the panels treated with this chemical in all series was only four per cent. There was no injury noticed to the inside of the test panels. Plate 11 shows these panels under H.

Zinc Naphthenate: There was no injury noticed on any of the panels treated with zinc naphthenate. This material was equal to copper naphthenate in preserving the pine panels. Plate 11 shows these panels under I.

Results: Figure 13 shows the total damage to the test panels in per cent for the eight preservatives as compared with the check. Of the materials tested zinc naphthenate and copper naphthenate gave the highest degree of protection. Chromated zinc chloride and "celcure" gave the least protection. Preservatives containing coal-tar products did not protect wood when placed in contact with soil. Although the active ingredients in "cuprinol #70" are not known, this preservative in these tests acted similar to the coal-tar preparations. Pentachlorophenol gave protection next to the naphthenate solutions in these tests. All injury

Plate 10.

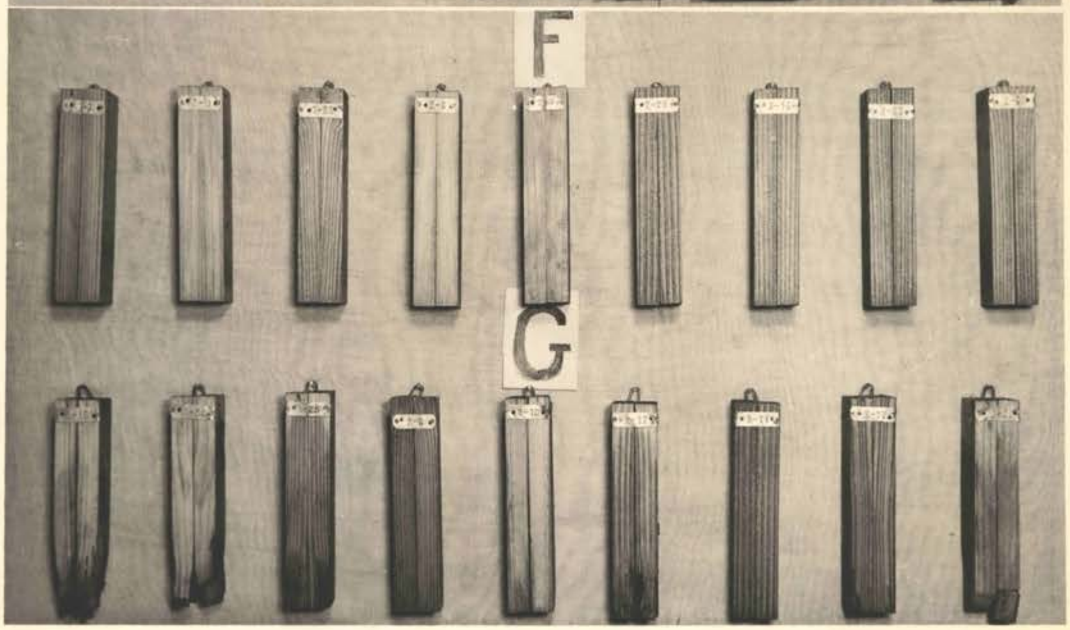
Test panels which had been given a five-minute soak in a wood preservative and exposed for thirty months in a termite infested area.

F - treated with copper naphthenate

G - treated with "Cuprinol #70"

J - untreated check


F
G


F
G


J

done to the panels treated with this material was on the surface and totaled only 4 per cent. All panels in the check were completely destroyed with an estimated damage of 85 per cent. Due to the almost complete destruction by termites, it was impossible to determine the amount of injury decay caused to the checks.

Plate 11

Test panels which had been given a five-minute soak in a wood preservative and exposed for thirty months in a termite infested area.

H - treated with pentachlorophenol

I - treated with zinc naphthenate

J - untreated check

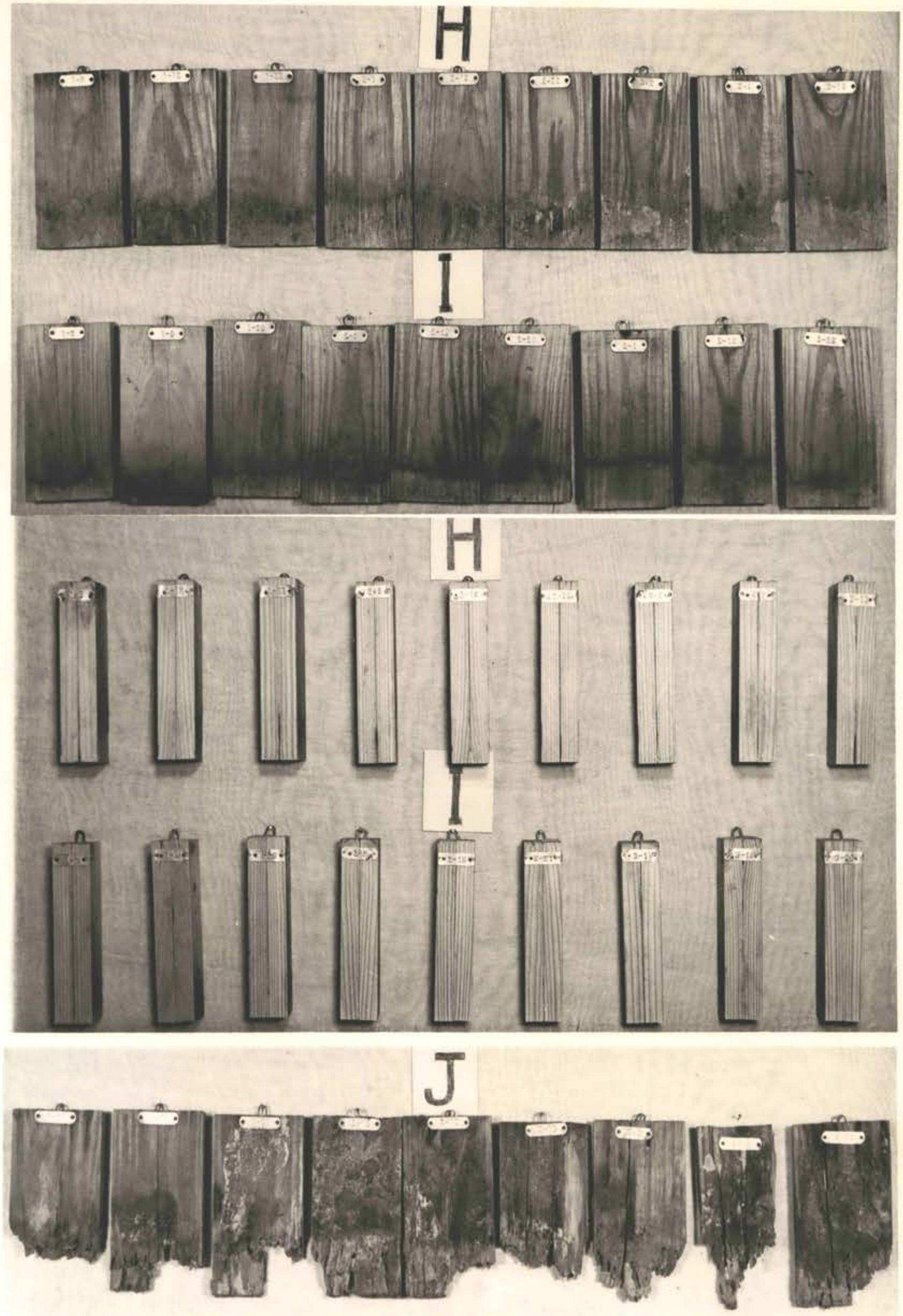
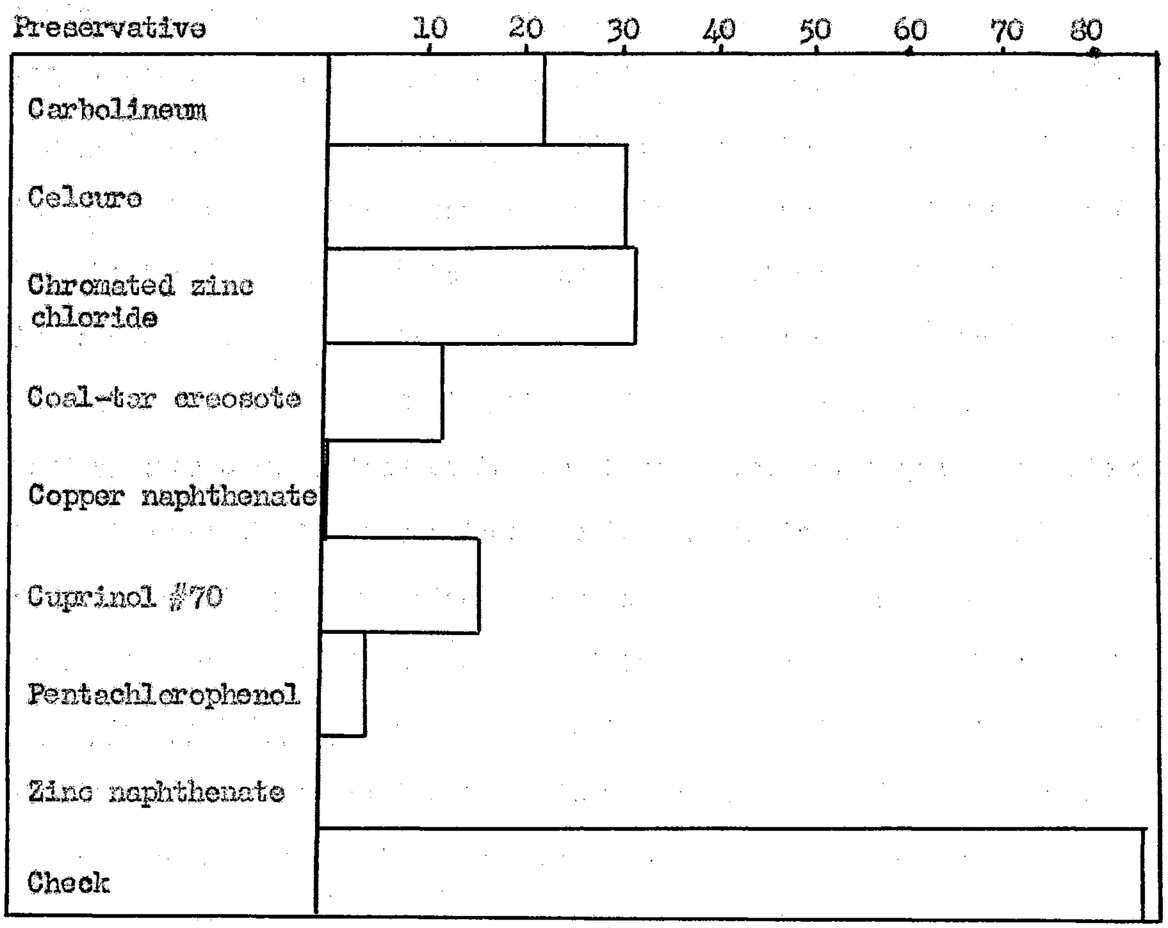

H
I
H
I
J

Figure 13.

The Per Cent of Treated Panels Destroyed by Decay and Termite Attack After Thirty Months Contact with Sandy Soil in a Termite Infested Area



RATING OF THE WOOD PRESERVATIVES TESTED

An over-all rating of the nine wood preservatives studied in these tests is given in Table 24. This rating is based on the following points: toxicity to the honeybee on contact, the effects of air drying on the various chemicals as to toxicity, the penetration into wood when given a five-minute soak, the protection afforded from decay and insect attack, and the cost. In order of their over-all effectivensss by this system of rating, with a possible score of three, the preservatives were as follows: zinc naphthenate, 3.0; pentachlorophenol, 2.8; copper naphthenate and copper 3-phenylsalicylate, 2.3; "cuprinol #70," 1.8; chromated zinc chloride and coal-tar creosote, 1.6; and carbolineum and "celcure," 1.5.

Table 24

Rating of Wood Preservatives for Use on Commercial Bee Farms

Wood Preservative	Contact Toxicity to Bees	Effects of Air Drying	Protection From Decay	Protection From Termites	Wood Penetration	Cost	Average Rating
Zinc Naphthenate	3	3	3	3	3	3	3.0
Pentachlorophenol	2	3	3	3	3	3	2.8
Copper Naphthenate	2	3	3	3	3	0	2.3
Copper 3-phenylsalicylate	2	2	3	3	3	1	2.3
Cuprinol #70	3	3	0	2	3	0	1.8
Chromated Zinc Chloride	3	3	0	0	1	3	1.6
Coal-tar Creosote	1	2	1	2	2	2	1.6
Carbolineum	1	2	0	2	2	2	1.5
Celcure	3	3	0	0	1	2	1.5

SUMMARY AND CONCLUSIONS

This study of wood preservatives in relation to beehive treatment was made during the period 1948 to 1953. The objectives were threefold: (a) to determine the relative toxicity of various wood preservatives to the honeybee as a hive treatment, (b) to determine the cost of treating the various parts of beehive equipment with wood preservatives and (c) to develop and evaluate an economical treatment program for use by the beekeeper.

The experiments conducted to determine the relative toxicity of certain wood preservatives were made under laboratory conditions. Pine panels were given a five-minute soak in the preserving material and then air dried for four different periods of time. The air drying periods were one day, seven days, twenty-eight days, and one hundred and eighty days. Small cages were fastened to the air dried treated panel and ten worker bees were caged against the treated surfaces. Observations were made over a seven-day period and mortality counts taken. The test bees were fed honey-candy during the test period. Ten series of tests were conducted with caged bees, each material tested in each series was replicated three times with a check. The wood preservatives thoroughly tested were carbolineum, "celcure," chromated zinc chloride, coal-tar creosote, copper 3-phenylsalicylate, copper naphthenate, "cuprinol number 70," pentachlorophenol, and zinc naphthenate. Observations were made of limited tests on the following materials: white paint, "Kelley's rot proofing compound," sodium pentachlorophenate, asphalt, and coal-tar creosote diluted with crankcase oil. Fumigations studies were conducted with carbolineum, coal-tar creosote, copper 3-phenylsalicylate, and pentachlorophenol. In addition to these tests contact mortality studies were made with ten solvents which are used as carriers for wood preserving chemicals.

Eight wood preservatives were studied as to cost in treating the different beehive parts. Two hundred and fifty-five pieces of beehive equipment were treated in determining the unit cost. To evaluate the five-minute soak treatment of hive preservation, suggested from these studies, accelerated stake tests were conducted for thirty months with eight wood preservatives in a termite infested area. The different preservatives were replicated nine times and were evaluated as to losses due to decay and termite attack.

The results obtained from the contact mortality tests clearly indicate the necessity of an ample air drying period of treated beehive equipment before use. Wood preservatives derived from coal-tar were more toxic to caged bees than any of the other preservatives tested. The mortality rates of caged bees were highly significant on panels treated with carbolineum, coal-tar creosote, and pentachlorophenol when air dried for one day. With the exception of copper 3-phenylsalicylate, the toxicity to test bees gradually reduced with an increase of the air drying time, until there was no significant difference between the check and the other eight preservatives at the end of twenty-eight days air drying. The fumigation studies indicate coal-tar derived preservatives produce fumes which cause honeybee mortality. No solvent tested was considered highly toxic to the honeybee by these contact tests.

When using a five-minute soak, a treatment that easily fits into the beekeeper's work program, the cost of treating bottom boards varied from one-half cent each for chromated zinc chloride to thirty-five cents for copper naphthenate. Preservatives dissolved in oil solvents penetrated the wood panels more readily and required more material for treatment than the aqueous solutions. Preservative cost ranged from twenty cents a gallon to four dollars and seventy cents, and the difference in preservative cost is reflected in the cost of treating the beehive parts. When evaluated from cost alone the following wood preservatives were considered satisfactory: zinc naphthenate, pentachlorophenol, "Kelley's rot proofing compound," chromated zinc chloride, and "celcure."

Studies to evaluate protection given treated wood from decay and termite attack indicate that oil soluble preservatives give more protection than those dissolved in water. Damage that occurred to test panels placed in contact with sandy soil in a termite infested area for thirty months ranged from zero for zinc and copper naphthenate to eighty-five per cent for the untreated check. In order of their resistance to wood rots and termite attack, with per cent damage, the preservatives were zinc naphthenate, 0; copper naphthenate, 0.5; pentachlorophenol, 4; coal-tar creosote, 12; "cuprinol #70," 16; carbolineum, 22; "celcure," 30; and chromated zinc chloride, 31.

Nine of the wood preservatives were rated according to toxicity to the honeybee, effects of air drying, protection from decay and termite attack, penetration and cost. In order of their effectiveness by this system of rating with a possible score of 3, the preservatives were as follows: zinc naphthenate, 3; pentachlorophenol, 2.8; copper naphthenate, and copper 3-phenylsalicylate, 2.3; "cuprinol #70," 1.8; chromated zinc chloride and coal-tar creosote, 1.6; and carbolineum and "celcure," 1.5.

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