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To the Graduate Council:

I am submitting herewith a thesis written by Alberto C. Febre entitled "A Study of the Abrasive Effects of Trifluralin, Diuron and Fluometuron on Spray Nozzles." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Mechanization.

Erwin K. Boyce
Major Professor

We have read this thesis and recommend its acceptance:

John Howell

Henry Andrews

Accepted for the Council:

Hilton A. Smith
Vice Chancellor for
Graduate Studies and Research

A STUDY OF THE ABRASIVE EFFECTS OF TRIFLURALIN, DIURON AND FLUOMETURON ON SPRAY NOZZLES

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Alberto C. Febre
August 1968

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ABSTRACT

The abrasive action of some chemical herbicides can cause wear in parts of the field sprayer. Such abrasion occurs in greater degree with liquid suspensions and wettable powders, due to low solubility and certain inert materials. The nozzle orifice tips increase in discharge capacity is important because it may result in unnecessary waste of spray material, possible crop damage and added cost of nozzle tip replacement. The objective of this study was to determine, the abrasive effect of trifluralin, diuron and fluometuron in varying concentrations, on different nozzle materials, size and total hours of use.

The nozzle tips wear test was conducted in a laboratory spray unit. The nozzle discharge was recalibrated volumetrically after 3.5-hour intervals. In this study, spraying systems 8001, 8002, 8003 and 8004 and Century 12 NF size nozzle tips were used. Tips made of brass, hardened stainless steel and nylon were tested. The amount of increase in nozzle discharge capacity ranged from -0.26 for nylon nozzle tips to 19.41 for brass nozzle tips. The abrasive effect of the spray mixture was more severe on the smaller size brass nozzle tips as compared to the larger brass nozzle tips. The increase in the discharge capacity of the brass

nozzle tips was directly related to the higher concentration of the diuron mixture. Brass nozzle tips increased discharge capacity much more than hardened stainless steel with diuron and fluometuron spray mixtures. The nylon nozzle tips showed a slight decrease in discharge capacity. The abrasivity of trifluralin, diuron and fluometuron was reduced with the continuous recirculation of the spray mixture. The increase in discharge capacity of brass nozzle tips was reduced when continuous fresh mixtures were used.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

CHAPTER I

THE PROBLEM

I. INTRODUCTION

The development of the American agriculture is due in part to the introduction of the agricultural machinery. These machines have contributed to the increase in production efficiency, reducing the man-hour requirement for the major crops with resulting higher yields, better quality and lower costs per crop unit (16).[1]

One restricting factor in production of food, feed and fiber is weeds. Weeds present a major problem because they may reduce quality and yield of the crop, and harvesting costs may be increased. In some cases, the mechanical harvesting of crops may be limited by the presence of weeds.

With the discovery of new and better selective herbicides, the old hand weeding method, the hoe hands, and some of the mechanical tillage and cultivation methods are being replaced by chemical weed control. In 1962, 28 percent of

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[1]The numbers appearing in parentheses refer to similarly numbered references in the Bibliography.

the harvested acreage of agronomic crops in the United States had some form of chemical weed control (1).

One piece of agricultural machinery whose use has been expanded is the field sprayer. With chemicals being developed to control weeds, the use of sprayers has increased rapidly and played an important role in the advancement of agricultural production.

The abrasive action of the spray chemical can cause wear in the sprayer pump, the pressure regulator valve and the nozzle orifice tips as well as any other part that is subject to the action of the chemical. Such abrasive action occurs in greater proportion with wettable powders generally due to their low solubility and inert material present.

The wear of the nozzle orifice tips is significant because it may change its capacity and will result with unnecessary waste of spray material, possible crop damage, and increased cost of nozzle tip replacement.

Turner (15) said,

> Quality of field or orchard spraying can be no better than the nozzle equipment will permit.

II. STATEMENT OF THE PROBLEM

When selecting a sprayer for the farm, consideration must be given to the type and size of the pump which must be able to deliver the out-put required at the recommended pressure and have some excess of capacity for hydraulic agitation and to compensate for internal wear of the pump.

Consideration must be given to the nozzle system because it is expected to apply the same rate at a constant speed and pressure to permit even coverage. The capacity of the nozzle is determined principally by the size of the orifice tip and internal passage and also by the system pressure. Most herbicides are applied at a pressure of not more than 40 psi. Any variation of the nozzle orifice tip will result in change of its capacity.

For the best results using herbicides the spray mixture must be applied at the desired rate. A rate higher than recommended, not only wastes expensive material and increases production costs, but also may damage the crop and may increase the herbicide concentration in the soil. A lower application rate which will not damage the crop, may not be effective, and may lead to increased weed growth. The herbicide must be applied at the optimum rate and time to be successful in controlling the weeds.

Wettable powder herbicides consists of finely divided solid particles of an active low solubility chemical which may be mixed with an inert material and is usually dispersed in water (11).

The use of wettable powder involves two problems, (1) the agitation of the spray mixture to prevent settling of the solid particles, and (2) the friction of the solid particles of the spray mixture that cause erosion of the nozzle orifice tips.

The wear of the nozzle orifice or its change of size is related also to the material from which it was made; some materials are more resistant to wear than others. Also different spray materials may show different wear characteristics.

Thus, it will aid farmers and others working with herbicide application to have a better knowledge of the wearing action of suspension and wettable powder mixtures on their spraying equipment.

III. OBJECTIVES OF THE STUDY

The objectives of this study were to determine the abrasive effect of an emulsion, a liquid suspension and a wettable powder spray mixture on the nozzle discharge capacity as related to (1) varying concentration of the chemicals, (2) the material from which the tips were made, whether brass, hardened stainless steel or nylon, (3) the size of the orifice tips, and (4) the total number of hours used.

CHAPTER II

REVIEW OF LITERATURE

An important consideration in chemical weed control is the abrasive action of some herbicide formulations particularly suspensions and wettable powders. This abrasion can cause the nozzle orifice to wear rapidly and as a result increase the discharge rate. A review of related literature follows.

Nixon (13) conducted one of the earlier experiment to determine the abrasive effect of a spray mixture of lime and Bordeaux mix on ten disk tips. The experiment showed that the orifices were enlarged unsymmetrically, having more wear at the exit than at the entrance of the opening.

French (5) stated on his experiment with a Bordeaux spray mixture that the brass disk tips was the only part that showed rapid wear. A large part of the wear occurred during the first few hours, probably due to rough edges left by the dill being rapidly worn away. He also reported that a stellite disk offered considerable greater resistance to wear than any other materials.

Turner (15) reported an experiment on the relation of nozzle tip wear with respect to different concentrations, and different metals. He reported a considerable increase in percent of wear with a 100 percent increase in concentration of the Bordeaux mixture and that some metals showed more wear resistance than others.

Kelly and Falkenstein (10) studied the abrasion action on a copper disk with a 1/32 inch hole, with a spray mixture using 125 gallons of water plus five pounds of the diluent with the following increase in percent of flow: 9.6 percent for gypsom and 6.5 percent for talc.

Marshall (12) conducted an experiment to find out relation of nozzle tip wear with respect to different metals, plastics and ceramics. The test concentrate was a finely divided insecticidal-grade pyrophyllite at a rate of one pound in one imperial gallon of water. Abrasion calculation was related to the percentage increase of area of the nozzle tip orifice on both faces. He reported that resistance to abrasion of steel or alloy nozzle disks, to some degree, corresponds with their hardness. High-grade rubber resists abrasive wear and polycithylene plastic showed the highest resistance to abrasion. The plastic expanded slightly at 100 degrees Fahrenheit as is generated by the pressure and pumping process.

Hendrickson (9) presented the results of an experiment on nozzle tips wear using a spray mixture of a low volatile ester of 2,4-Dichlorophenoxyacetic Acid (2,4-D) at the rate of one ounce per one gallon water. The results showed that the wear rate was the greatest during the first 100 hours of use. He also stated that where rate of application is critical, it may be advisable to calibrate all the nozzles and to select those with approximately the same discharge.

Wylie and Boyce (18) reported an experiment using wettable powder herbicide at rates within the limits for crop application and spray nozzles of brass, hardened stainless steel and nylon. Using 2-chloro-4,6-bis-(ethylamino)-s-triazine (simazine) at rate of two pounds of active ingredient plus 20 gallons of water, the experiment showed the highest percent of increase in discharge capacity for brass nozzle tips. The percent increase in discharge capacity was lower when a large size nozzle tip was used. The hardened stainless showed a 1.18 percent average increase in discharge while there was a 6.58 percent increase for the same size of brass nozzle tip in a 10.5 hour of test. Using 2-chloro-4-ethylamino-6-isopropylamino-s-triazine (atrazine) at the same concentration, the discharge increase of a hardened stainless steel nozzle tip was 0.65 percent when the brass nozzle tip of the same size was 3.74 percent of increase discharge. The wear test of nylon nozzle tips using atrazine at same rate for 10.5 hours showed an increase in discharge capacity of 0.03 percent, another set of nylon nozzles showed a decrease of 3.6 percent. A test also was conducted on actual field conditions, spraying 45 acres, the brass nozzle tips showed an average percent increase in discharge capacity of 11.8 percent.

Wooten, Parker and Holstun (17) studied the abrasiveness of 3-(3,4-Dichlorophenyl)-1,1-Dimethylurea (diuron) formulated as wettable powder and as a liquid suspension. They reported that the wettable powder was slightly more abrasive to brass than the liquid suspension. In a 30 hour test using 0.4 gpm brass tips, the wettable powder formulation increased nozzle capacity 9.5 percent and the liquid suspension increased nozzle capacity 8.5 percent. The highest change in discharge capacity occurred in the first hour of wear. Water alone caused a 4 percent flow increase in 30 hours.

Dumas (4) presented an experiment with diuron wettable powder and diuron formulated as liquid suspension at the rate of one pound of diuron plus 25 gallons of water. In this experiment the spray mixture was drained after three hours of recirculation and a new mixture added to prevent the particles from wearing smooth because of continuous recirculation. Using brass nozzle tips rated at 0.336 gpm, the diuron wettable powder (DW) was more abrasive than diuron liquid suspension (DL).

Doll, Knake and Bullet (3) stated that 2-chloro-N, N-diallylacetamina (CDAA) a liquid herbicide also enlarges the nozzle orifice and that the out-put increased at a greater rate when the nozzle tips were first used. After some hours of use the change in wear was smaller.

Patel (14) conducted an experiment with several concentrations of atrazine and 4-(methylsulfonyl)-2, 6-dinitro-N, N-dipropylaniline (nitralin) formulated as wettable powder herbicides with different sizes and types of nozzle tips. He found an increase in nozzle discharge capacity from 0.00 percent to 27.65 percent. The increase in the discharge capacity of the nozzle tips resulting from wear was directly related with the concentration. The brass nozzle tips increase in discharge capacity was greater and more rapid than that of hardened stainless steel nozzle tips. The nylon nozzle tips showed a decrease in the discharge capacity; this decrease was larger in the smaller sizes. Also he stated that with equal concentration, nitralin formulation was more abrasive than atrazine.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. TEST EQUIPMENT

Wear Test Equipment

The equipment used for the wear tests was a laboratory spray unit. The tank was made of a 55 gallon drum, cut in half on the long axis and set in an angle iron frame. The inlet of the pump, located in the bottom of the tank was protected by a 50 mesh stainless steel suction strainer using a three-quarter-inch hose and three-quarter-inch pipe.

The pump used in the experiment was a Delavan, Model 7-2110 with Ni-Resist alloy body, end plate and rotor with seven nylon rollers. The power required to operate the pump was supplied by a three-quarter-horsepower electric motor. A V-belt drive was used between the electric motor and the pump to reduce the motor speed to 550 revolutions-per-minute at the pump.

The discharge side of the pump was connected to a line strainer which contained a 50-mesh screen, To avoid pressure fluctuations, a small surge tank was located in the line, after the strainer.

A line with a valve was connected to the pressure side of the system between the strainer and the surge tank to operate the hydraulic agitator. This hydraulic agitator system consists of two jet agitators, with three No. 2 orifice nozzles, fixed on the bottom of the tank for hydraulic agitation.

A diaphragm pressure regulator valve was installed between the surge tank and the boom. This valve was used to adjust and maintain the operating pressure on the boom. This valve also has a by-pass line to return the excess liquid to the tank. A pressure gauge was located between the diaphragm pressure regulator and the boom. The 3.5 foot long boom with six evenly spaced nozzles was installed over the tank so the sprayed liquid could be collected and recirculated.

Equipment for Calibration

The nozzle calibration equipment was used to determine the flow rate of the nozzles before and after the wear tests. A fixture to test one nozzle each time was connected to the city water system, using a quick-cut-off valve, a pressure regulating valve and a pressure gage to calibrate the nozzle at the required pressure. A 2000 ml graduated cylinder was used to collect the discharge over a period of time.

II. TEST MATERIALS

Nozzles

One of the most important parts of the sprayer is the nozzle because it influences the even and accurate rate of application of the spray mixture. Any wear of the nozzle orifice may cause a change in the application rate. Each nozzle must be checked for accurate rate.

Nozzles are classified by the delivery pattern. These different patterns are: (1) flat or fan, (2) solid cone, (3) hollow cone. Each type of nozzle is also classified by capacity and the flat or fan type is classified according to the spray angle. The material from which nozzles are made is another basis for classification. These classifications apply specifically to the nozzle orifice tip which determines the type, angle and volume of the spray out-put. The tips are easily removed and replaced. The flat fan type is specified for many types of herbicides because it produces a narrow elliptical spray pattern, which gives uniform coverage. Most flat-type nozzle tips are marked with four digits. The first two refer to the angle of spray pattern, the third digit stands as a decimal point for the fourth digit which refers to the nozzle discharge capacity in gallons per minute at a pressure of 40 pounds per square inch. In this study, the 8001, 8002, 8003, and 8004 sizes nozzle tips were used.

Tipe made of three different materials were tested. These materials were brass, hardened stainless steel and nylon.

The brass and hardened stainless steel tips were manufactured by Spraying Systems Co., Bellwood, Ill., and the nylon nozzles were manufactured by the Century Engineering Corporation, Cedar Rapids, Iowa. A system based on small cuts or notches was used for individual identification of each nozzle tip.

Trifluralin

Trifluralin, a product of Elanco Products Company, is an emulsificable concentrate containing 44.5 percent N, N-di-n-propyl-2, 6-dinitro-4-trifluromethyl amiline as active ingredient. Solubility in water is 24 ppm at 27 degrees centigrade. It is recommended as a pre-plant incorporated herbicide for control of annual grasses, Johnsongrass (Sorghum halepense (L.) Pers) from seed and some broad-leaved weeds in soybean (Glycine Max (L.) Merr.) and cotton (Gossypium species) at rate of 0.5 to one pound active ingredient per acre on a broadcast basis treated, depending on type of soil. In this study was used a heavy concentration of 0.5 pound trifluralin plus water to make five gallons of spray mixture in accordance with the capacity of the spray tank.

Diuron DL

Diuron DL, a product of E. I. Du Pont de Nemours & Co.

The fluometuron in this study was used at a concentration of one pound active ingredient in five gallons of water.

III. TEST PROCEDURES

Nozzle Calibration

To calibrate the nozzle orifice tips, the following method was adapted:

The nozzle orifice tip was placed in the nozzle body of the nozzle calibration equipment. The water was turned on and the pressure was adjusted to 40 psi by means of the pressure regulator valve. After air was bled from the system, the nozzle tip discharge was collected in the 2000 ml graduated cylinder for one minute and the graduate cylinder was removed. This calibration procedure was repeated three times. To convert ml per minute to gallons per minute, the conversion factor of 0.0002642 was used.

Nozzle Wear Test

The following method was used to determine the possible wear on the nozzle orifice tips:

The groups of three nozzle orifice tips were marked for identification purpose and checked for discharge capacity on the nozzle calibration equipment before the wear test.

The chemical herbicide was mixed with water, following manufacturing recommendation and then the required amount of water was added in the tank. The pump was run for approximately 15 minutes to mix the suspension with the help of the hydraulic agitator. The nozzle orifice tips and the 50-mesh nozzle strainers, were then installed in the nozzle bodies on the boom of the equipment. Each nozzle orifice tip was marked with an identification notch corresponding to its position on the boom. Two different groups of three nozzle tips each, were tested each time. The pressure operating of 40 psi was adjusted using the pressure regulator valve at the beginning of the test period of 3.5 hours, and maintained at the same value throughout the test. After three and one-half hours, the wear test was stopped and all the nozzle orifice tips and strainer were removed and cleaned with plain water. Then the nozzle orifice tips were rechecked on the nozzle calibration equipment to determine any possible change indischarge capacity caused by wear and the results were recorded. To prevent the spray material from settling out in the tank, the pump was run during the time the nozzles were being rechecked. The three and one-half hours base tests were repeated with the same mixture and nozzle tips, until two successive tests showed no variation in the discharge capacity.

CHAPTER IV

DISCUSSION OF RESULTS

Trifluralin, diuron, and fluometuron were used as the spray material for the wear tests to determine changes in nozzle tips discharge capacity. In this study, four brass nozzle tips of different sizes, one hardened stainless steel nozzle tips of one size and a nylon nozzle tip were tested with different concentrations of the herbicides. The discharge of nozzle tips were determined before and after a three and one-half hour test interval. The spray material was replaced after each wear test, and new and previously used nozzle tips were tested.

One test was conducted using trifluralin as the spray material with two different sizes of nozzle tips. Six wear tests were completed using diuron, formulated as a liquid suspension, using two different concentrations and several types and sizes of nozzle tips. Fluometuron, formulated as a wettable powder, was used on five wear tests with the same concentration and several types of nozzle tips. The concentration of the herbicides used was, in general, within the limits recommended for application to crops. The rates of chemical herbicides refer to pounds of active ingredient.

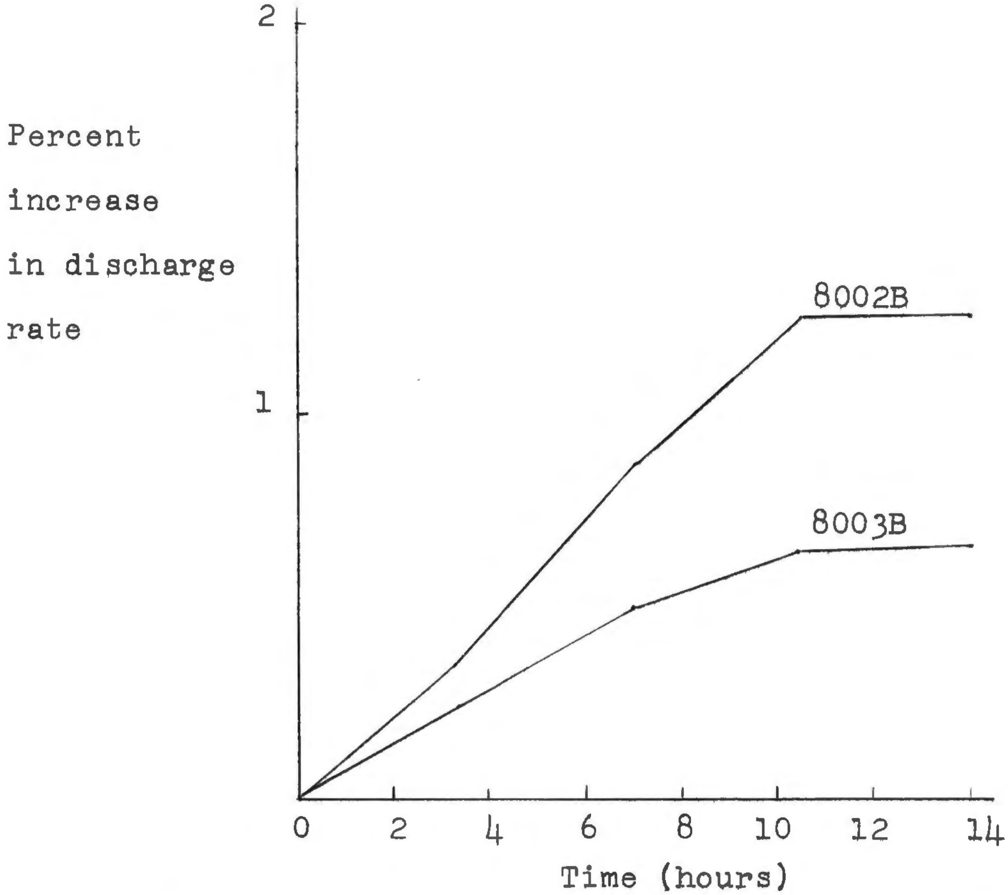

Figure 1. Average percentage change in discharge rate of 8002 brass and 8003 brass nozzle tips. The spray material of 0.5 pound of trifluralin and water to make five gallons of mixture was run at 40 psi.

III of the Appendix.

The average increase in discharge capacity of 8002 and 8003 brass nozzle tips was 6.47 and 6.07 percent, respectively. After 17.5 hours of operation there was no additional change in discharge.

Wear test III was conducted with diuron at the rate of 1.05 pounds of active ingredient and enough water to make five gallons of mixture. Three 8001 and three 8002 brass nozzle tips were tested. The three 8002 brass nozzle tips were used previously in test II. An attempt was made to determine the effect of fresh chemical mixture on previous used nozzles. This wear test was run for a total of 21 hours. The results of this wear test are shown in Figure 3. Complete wear test data are located in Table IV of the Appendix.

The average increase in the discharge capacity of 8001 and 8002 brass nozzle tips was 19.41 percent and 11.46 percent, respectively. After 17.5 hours of operation there was no additional change in discharge. The concentration of the spray mixture in the test caused an increase in the percent capacity of the used 8002 brass nozzle tips.

In wear test IV, the experiment was conducted with diuron at the rate of 0.44 pounds of active ingredient and enough water to make seven gallons of spray mixture. This wear test was run for 17.5 hours of operation. Three 8001 brass nozzle tips and three 8003 brass nozzle tips were

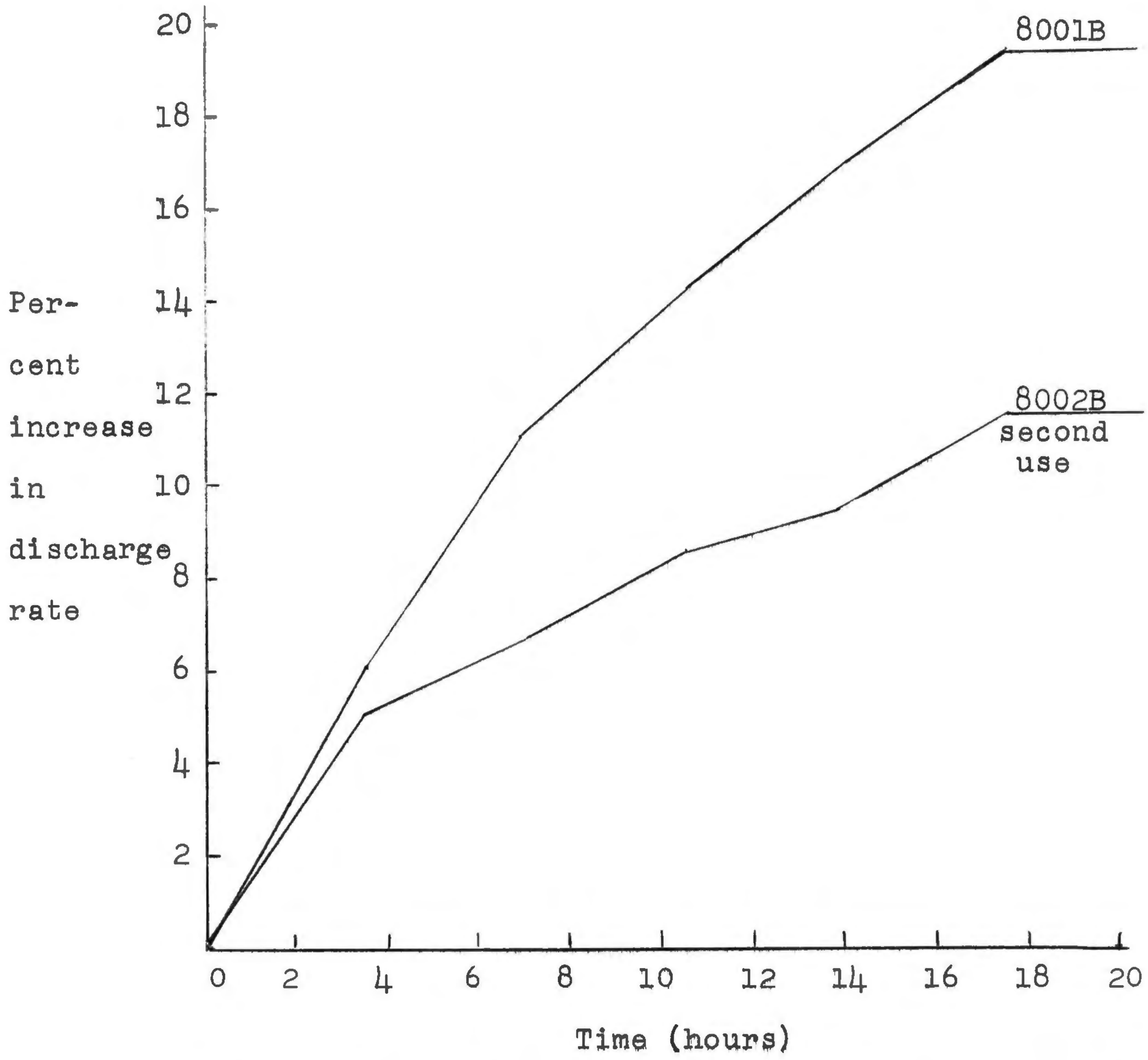

Figure 3. Average percentage change in discharge rate of 8001 new brass and 8002 used brass nozzle tips. The spray material of 1.05 pounds of diuron and water to make five gallons of mixture was run at 40 psi.

tested. The results of this wear test are shown in Figure 4. Complete wear test data are shown in Table V of the Appendix.

The average increase in discharge capacity of 8001 and 8003 brass nozzle tips were 11.30 percent and 5.68 percent, respectively. There was no additional change in discharge capacity after 14 hours of operation.

In wear test X the experiment was conducted with diuron at the rate of 0.44 pounds of active ingredient and enough water to make seven gallons of solution. A severe leak occurred in the pump during the time that this test was run, and at the end of the test the pump was replaced. Three 8002 hardened stainless steel and three 8004 brass nozzle tips were tested. This wear test was run for a total of 17.5 hours. The results of this wear test are shown in Figure 5. Complete wear test data are shown in Table VI of the Appendix.

The average increase in the discharge rate of the 8002 hardened stainless steel and 8004 brass nozzle tips was 1.01 percent and 8.30 percent, respectively.

In this test, the 8002 hardened stainless steel nozzle tips showed no increase in discharge capacity after seven hours of use and the 8004 brass nozzle tips showed continued increase in discharge capacity thru 17.5 hours of use.

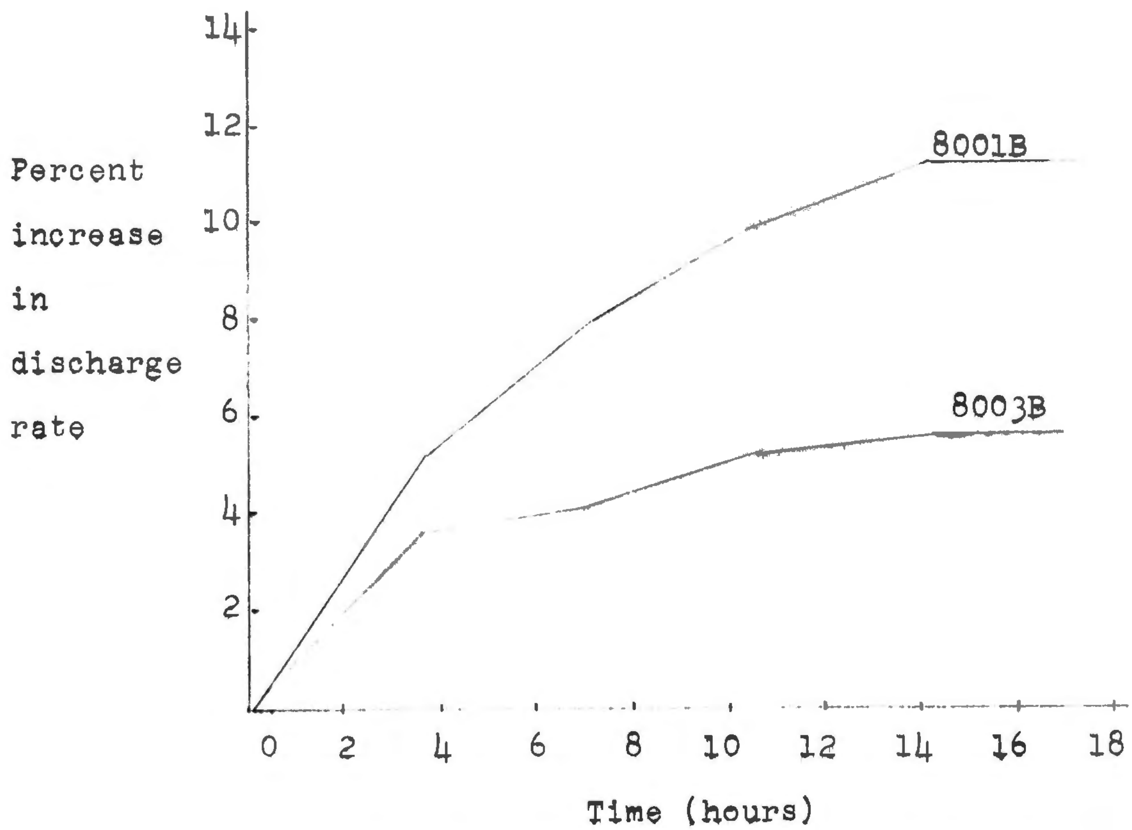

Figure 4. Average percentage change in discharge rate of 8001 brass and 8003 brass nozzle tips. The spray material of 0.44 pound of diuron and water to make seven gallons of mixture was run at 40 psi.

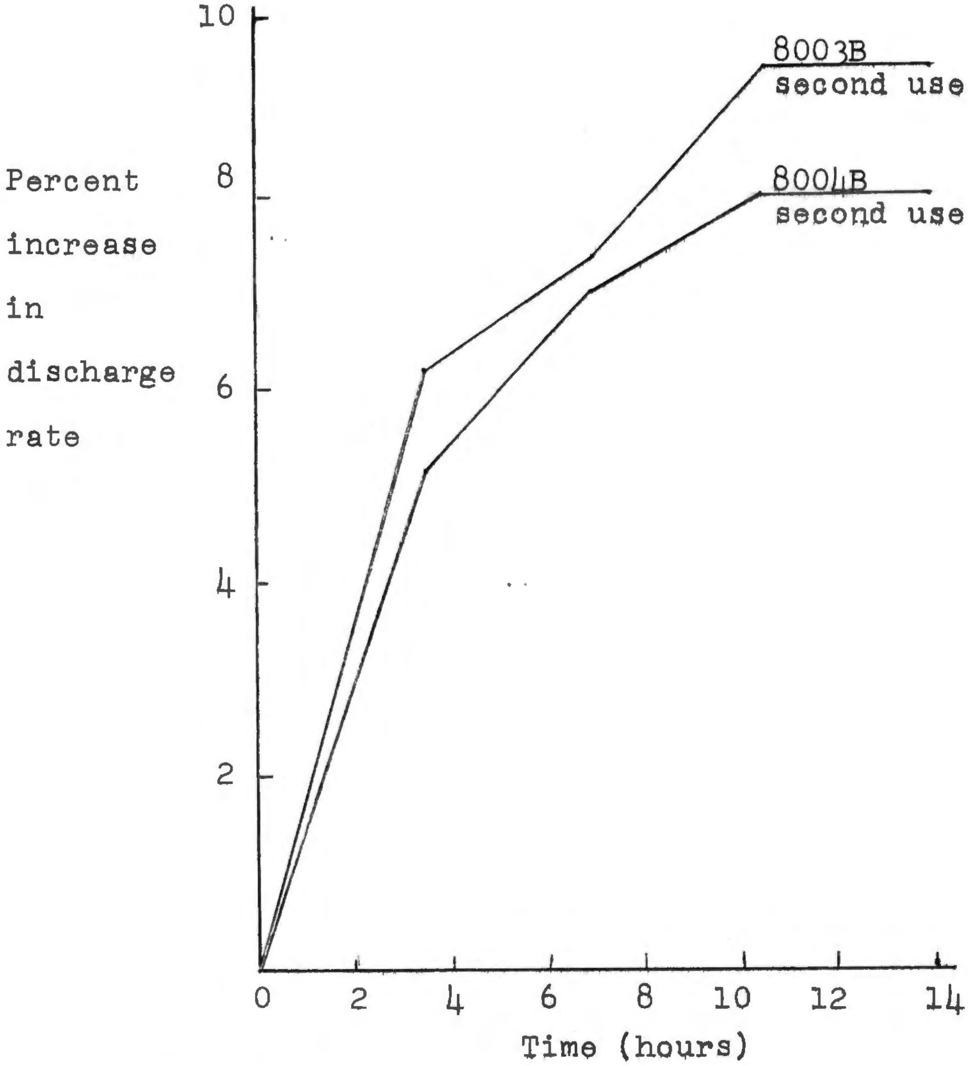

Figure 6. Average percentage change in discharge rate of 8003 brass second use and 8004 brass second use nozzle tips. The spray material of 1.05 pounds of diuron and water to make five gallons of mixture was run at 40 psi.

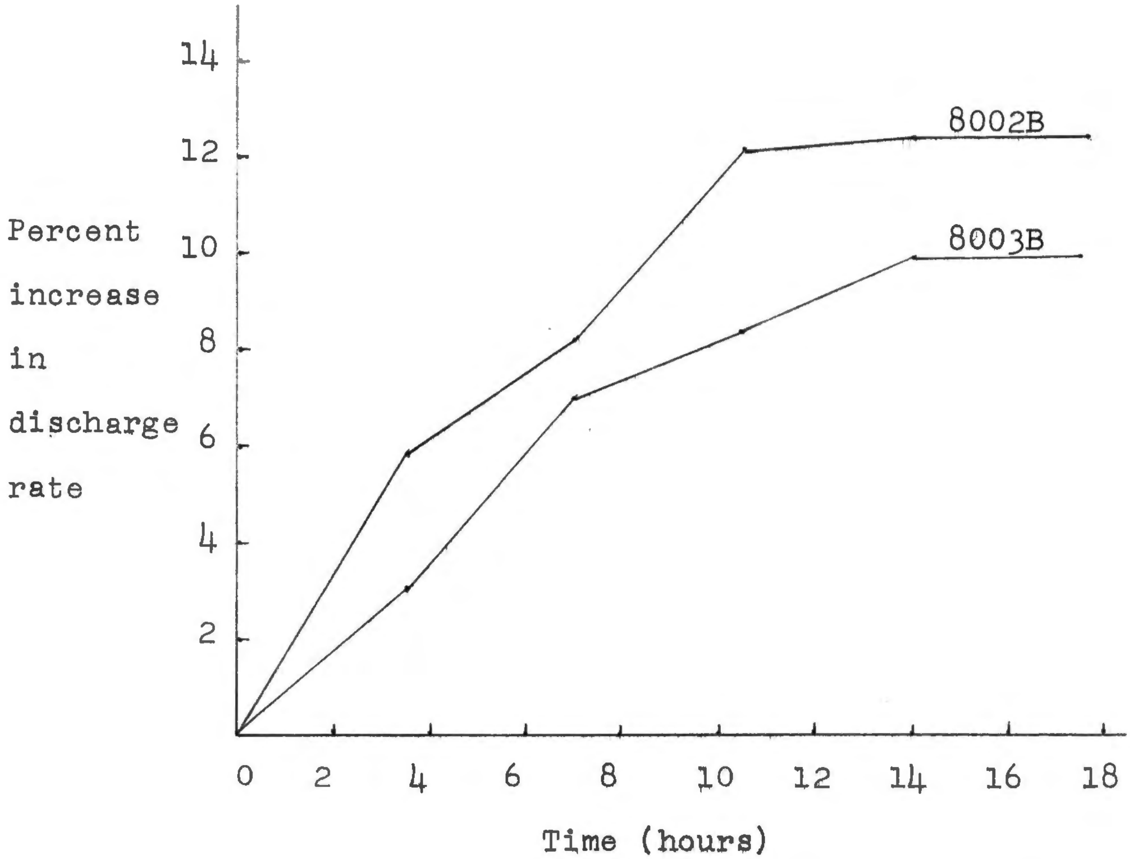

Figure 7. Average percentage change in discharge rate of 8002 brass and 8003 brass nozzle tips. The spray material of 1.05 pounds of diuron and water to make five gallons of mixture was run at 40 psi.

Results of Fluometuron Tests

Wear test V, was conducted with fluometuron, formulated as a wettable powder with a concentration of one pound of active ingredient and enough water to make five gallons of mixture. Three new 8002 brass and three previously used 8002 brass nozzle tips were tested. The experiment was made to determine the abrasion action of the spray mixture in percent increase of capacity on new and previously used brass nozzle tips of same size. The results of this wear test are shown in Figure 8. Complete wear test data are shown in Table IX of the Appendix.

After 10.5 hours of operation, the average increase in the discharge rate of the new 8002 and used 8002 brass nozzle tips was 8.01 percent, and 4.67 percent, respectively. There was no additional change in discharge after 10.5 hours of operation.

Wear test VI, was run for a period of 14 hours with a concentration of one pound active ingredient of fluometuron and enough water to make five gallons of mixture. Three 8002 brass nozzle tips previously used in test V, and three 8002 brass nozzle tips previously used on second time in test V, were tested. The results of this wear test are shown in Figure 9. Complete wear test data are shown in Table X of the Appendix.

The average increase in the discharge capacity of the 8002 brass nozzle tips used on second time and the 8002 brass nozzle tips used on third time was 4.06 percent, and 2.06 percent, respectively. It showed that wear characteristics of this nozzle decreased when used on second and third time with fresh mixtures. After 10.5 hours of operation there was no additional change in discharge.

Wear test VII, was run for a period of 14 hours with a concentration of one pound active ingredient of fluometuron and enough water to make give gallons of mixture. Three 8001 brass and three 8004 brass nozzle tips were tested. An attempt was made to compare the action of the spray mixture on the discharge capacity in the smaller and the larger brass nozzle tips tested. The experiment showed that the percent increase in discharge capacity was more severe in the smaller size brass nozzle tips when compared with the larger ones. The results of this wear test are shown in Figure 10. Complete wear test data are shown in Table IX of the Appendix.

The average increase in the discharge capacity of the 8001 brass and 8004 brass nozzle tips was 12.31 percent, and 5.44 percent, respectively. After 10.5 hours of operation there was no additional change in discharge capacity.

Wear test VIII, was conducted for a period of 14 hours with a concentration of one pound active ingredient of fluometuron and enough water to make five gallons of mixture.

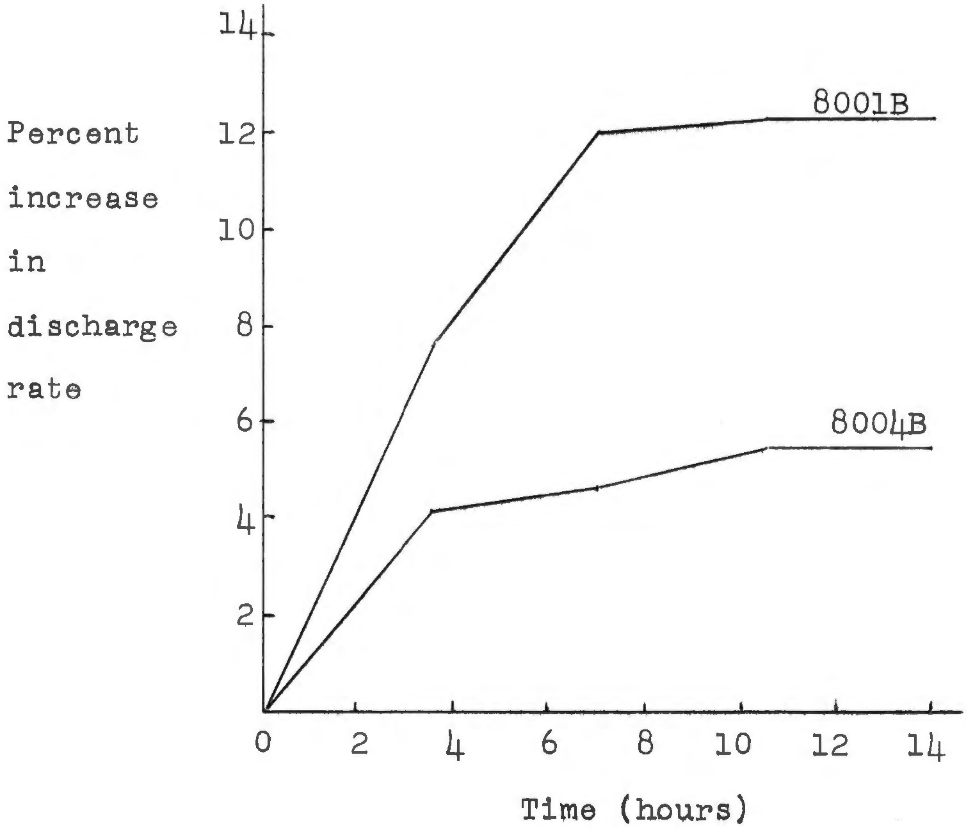

Figure 10. Average percentage change in discharge rate of 8001 brass and 8004 brass nozzle tips. The spray material of one pound of fluometuron and water to make five gallons of mixture was run at 40 psi.

Three 8001 brass nozzle tips previously used in test VII, and three 8004 brass nozzle tips also previously used in test VII, were tested. The experiment was made to compare the change in the discharge capacity in the larger and the smaller nozzle tips tested in second use. The results of this wear test are shown in Figure 11. Complete wear test data are shown in Table XII of the Appendix.

After 10.5 hours of use, the average increase in discharge capacity of the 8001 and 8004 brass nozzle tips was 6.29 percent, and 2.18 percent, respectively.

Wear test IX, was conducted for a period of 14 hours with a concentration of one pound active ingredient of fluometuron and enough water to make five gallons of mixture. Three 8002 hardened stainless steel, and three 12NF nylon nozzle tips were tested. The results of this wear test are shown in Figure 12. Complete wear test data are shown in Table XIII of the Appendix.

After 10.5 hours of operation, the average increase in discharge capacity of the 8002 hardened stainless steel and 12 NF nylon nozzle tips was 1.51 percent increase, and -0.26 percent decrease, respectively.

Inter-relationship of Wear Characteristics

A higher increase in percent change in discharge capacity of brass nozzle tips was caused with the higher

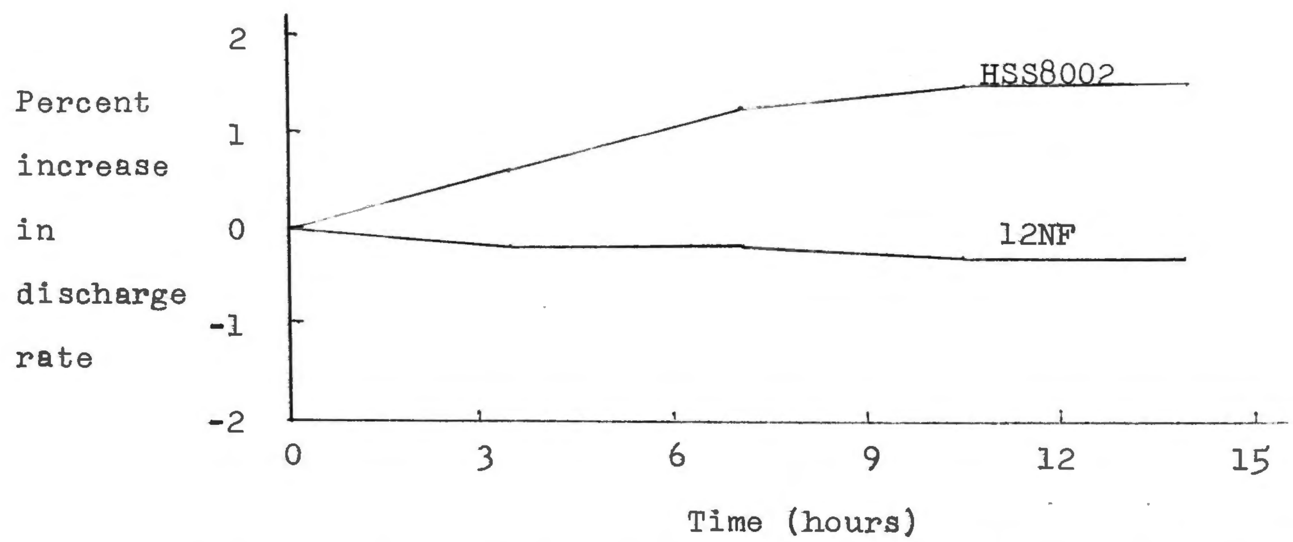

Figure 12. Average percentage change in discharge rate of HSS 8002 hardened stainless steel and 12NF nylon nozzle tips. The spray material of one pound of fluometuron and water to make five gallons of mixture was run at 40 psi.

concentration of the diuron mixture. The smaller capacity brass nozzle tips were more affected in high initial and total wear than the larger size of brass nozzle tips with a diuron mixture. The low concentration of diuron mixture caused less wear in percent change in discharge capacity on the larger size brass nozzle tips compared with the smaller brass nozzle tips. These relationships are shown in Figure 13. In wear test III, the average increase in the discharge rate of 8001 brass nozzle tips, at 3.5-hour periods, was 6.14 percent, 11.30 percent, 14.25 percent, 16.95 percent, and 19.41 percent with 1.05 pounds of diuron and five gallons of water. In wear test IV, the average increase in the discharge rate of 8001 brass nozzle tips, was 5.65 percent, 8.11 percent, 10.07 percent, and 11.30 percent, with 0.44 pounds of diuron with seven gallons of water. In wear test XII, the average increase in the discharge rate of 8002 brass nozzle tips at 3.5-hour periods, was 5.85 percent, 8.34 percent, 11.21 percent, and 12.45 percent with 1.05 pounds of diuron and five gallons of water. Using the lower concentration of diuron in wear test II, the average increase in discharge rate of 8002 brass nozzle tips, was 2.36 percent, 4.35 percent, 5.47 percent, 5.60 percent and 6.47 percent. In wear test XII, the average increase in discharge rate of 8003 brass nozzle tips, at 3.5-hour interval, was 3.13 percent, 7.03 percent, 8.47 percent, and 9.91 percent

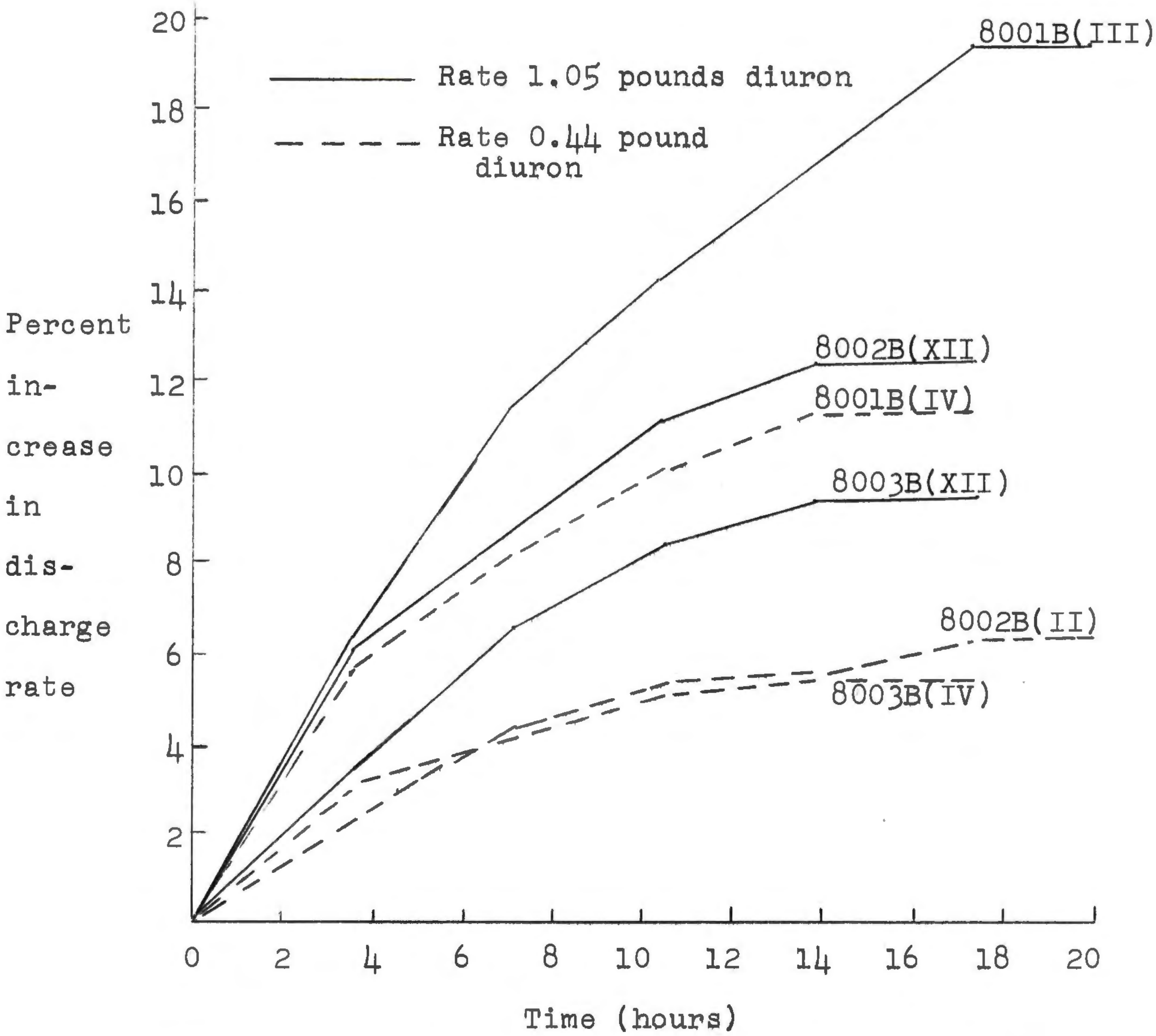

Figure 13. Average percentage change in discharge rate of nozzles at 40 psi. The 8001B in wear test III, 8002B in wear test XII and 8003B in wear test XII were tested with 1.05 pounds of diuron in five gallons of water. The 8001B in wear test IV, 8002B in wear test II and 8003B in wear test IV were tested with 0.44 pound of diuron in seven gallons of water.

with 1.05 pounds of diuron and five gallons of water. In wear test IV, the average increase in discharge rate of 8003 brass nozzle tips, at 3.5-hour period, was 3.64 percent, 4.24 percent, 5.33 percent, and 5.68 percent, using a concentration of 0.44 pounds of diuron in seven gallons of water.

The abrasive effect of fluometuron and diuron mixtures varied with respect to the type of nozzle material. As expected, the brass nozzle tips were much more susceptible to wear than hardened stainless steel. The brass nozzle tips received higher initial and total wear compared with hardened stainless steel of the same size, Nylon nozzle tips, about the same size of the brass and hardened stainless steel, in this study, showed a decrease on its original capacity. These relationships are shown in the Figure 14 and 15. Using the same concentration of one pound of fluometuron and five gallons of water in wear tests V and IX, the higher initial wear rates, in the discharge capacity of 8002 brass, 8002 hardened stainless steel, and 12NF nylon was 4.00 percent, 0.70 percent, and -0.13 percent, respectively. The total wear in discharge capacity in the same tests V and IX of 8002 brass, 8002 hardened stainless steel, and 12NF nylon was 8.01 percent, 1.51 percent, and -0.26 percent, respectively. In wear tests II and X, using 0.44 pounds of diuron

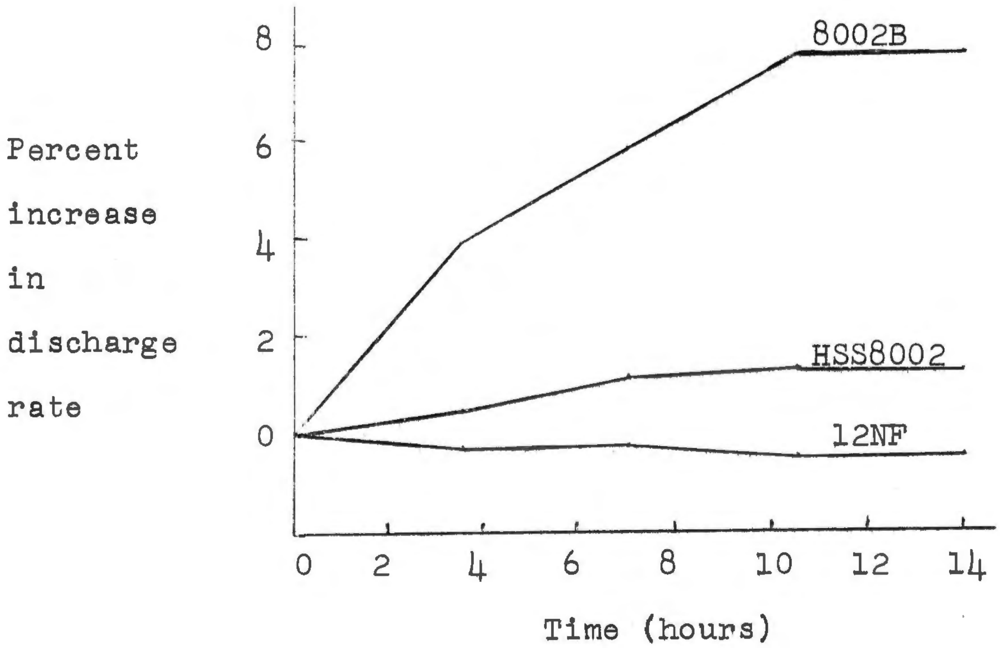

Figure 14. Average percentage change in discharge rate of 8002 brass, 8002 hardened stainless steel and 12NF nylon nozzle tips. The spray material of one pound of fluometuron and water to make five gallons of mixture was run at 40 psi.

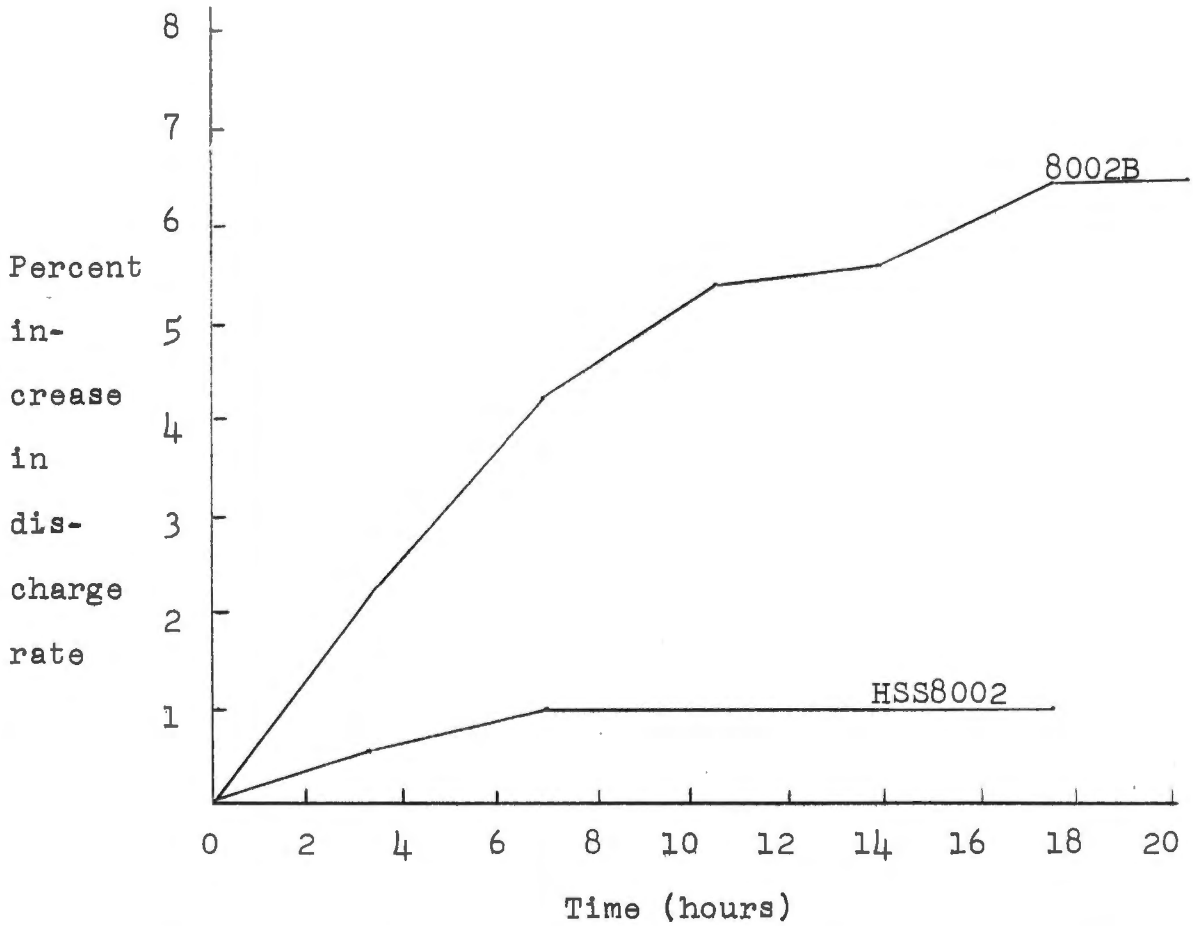

Figure 15. Average percentage change in discharge rate of 8002 brass and 8002 hardened stainless steel nozzle tips. The spray material of 0.44 pound of diuron and water to make seven gallons of mixture was run at 40 psi.

and seven gallons of water, the higher initial wear rate in the discharge capacity of 8002 brass nozzle tips, and 8002 hardened stainless steel was 2.36 percent and 0.63 percent, respectively. In the same tests II and X, the total wear in the discharge capacity of 8002 brass nozzle tips and 8002 hardened stainless steel was 6.47 percent, and 1.01 percent, respectively.

The abrasivity of trifluoralin, diuron and fluometuron mixtures was reduced with the continuous use of the spray mixture. Research (5, 14, 18) had shown decrease of abrasive effect due to continuous recirculation. The results of this study of the abrasive effect with respect to time is shown in Table I.

The total abrasive effect of the chemical mixture after a 14-hour test proved to be more severe on brass nozzle tips during its first use than in the second or third use, when a fresh mixture was added in the second and third tests.

However, the difference in abrasive action of the fresh mixture when compared to a mixture previously tested for 10.5 hours is shown by comparing the last three hours of test VII with the first 3.5 hours of test VIII. The former showed almost no wear whereas the latter increased out-put 6 percent. This difference is due to the abrasivity of the chemical as affected by the time of use. Therefore, the friction affects not only the nozzle tips but the particles

TABLE I

AVERAGE PERCENTAGE INCREASE IN DISCHARGE RATE OF SPRAYER NOZZLE TIPS AT 3.5-HOUR INTERVALS AT 40 psi SPRAY MATERIALS: TRIFLURALIN, DIURON AND FLUOMETURON

Wear Test No.	Nozzle Type	Average percent increase in discharge rate: After 3.5 hrs. use	After 7 hrs. use	After 10.5 hrs. use	After 14 hrs. use	After 17.5 hrs. use	After 21 hrs. use
I	8002B	0.37	0.87	1.25	1.25	----	----
	8003B	0.25	0.50	0.67	0.67	----	----
II	8002B	2.36	4.35	5.47	5.60	6.47	6.47
	8003B	1.26	3.20	4.20	5.23	6.07	6.07
III	8001B	6.14	11.30	14.25	16.95	19.41	19.41
	8002B	5.14	6.60	8.65	9.47	11.46	11.46
IV	8001B	5.65	8.11	10.07	11.30	11.30	----
	8003B	3.64	4.24	5.33	5.68	5.68	----
V	8002B	4.00	6.13	8.01	8.01	----	----
	8002B	2.87	3.47	4.67	4.67	----	----
VI	8002B	1.85	3.93	4.06	4.06	----	----
	8002B	1.49	1.83	2.06	2.06	----	----
VII	8001B	7.53	12.06	12.31	12.31	----	----
	8004B	4.09	4.60	5.44	5.44	----	----
VIII	8001B	6.29	6.29	6.29	6.29	----	----
	8004B	1.46	1.94	2.18	2.18	----	----
IX	8002HSS	-0.63	1.26	1.51	1.51	----	----
	12NF	-0.13	-0.13	-0.26	-0.26	----	----
X	8002HSS	0.63	1.01	1.01	1.01	1.01	----
	8004B	1.93	4.63	5.92	6.75	8.30	----
XI	8003B	6.20	7.40	9.31	9.31	----	----
	8004B	5.17	7.07	8.02	8.02	----	----
XII	8002B	5.85	8.34	11.21	12.45	12.45	----
	8003B	3.13	7.03	8.47	9.91	9.91	----

in the suspension being used. These relationships are shown in Figure 16.

In wear test VII, the average increase in the discharge capacity of the 8001 new brass nozzle tips, at 3.5-hour periods, was 7.35 percent, 12.06 percent and 12.31 percent, respectively. In wear test VIII, the average increase in the discharge capacity of the 8001 brass nozzle tips, previously used, at 3.5-hour intervals, was 6.29 percent. In wear test V, the average increase in the discharge capacity of new 8002 brass nozzle tips, at 3.5-hour intervals, was 4.00 percent, 6.13 percent, and 8.01 percent, respectively. In the same wear test V, the average increase in discharge capacity of a previously used, on second time 8002 brass nozzle tips, at 3.5-hour periods, was 2.87 percent, 3.47 percent, and 4.67 percent. In wear test VI, the average increase in the discharge capacity of a previously used, on third time 8002 brass nozzle tips, at 3.5-hour intervals, was 1.49 percent, 1.83 percent, and 2.06 percent, respectively. In wear test VII, the average increase in the discharge capacity of the new 8004 brass nozzle tips, at 3.5-hour periods, was 4.09 percent, 4.60 percent and 5.44 percent. In wear test VIII, the average increase in the discharge capacity of the 8004 brass nozzle tips, previously used one time, at 3.5-hour intervals, was 1.46 percent, 1.94 percent and 2.18 percent.

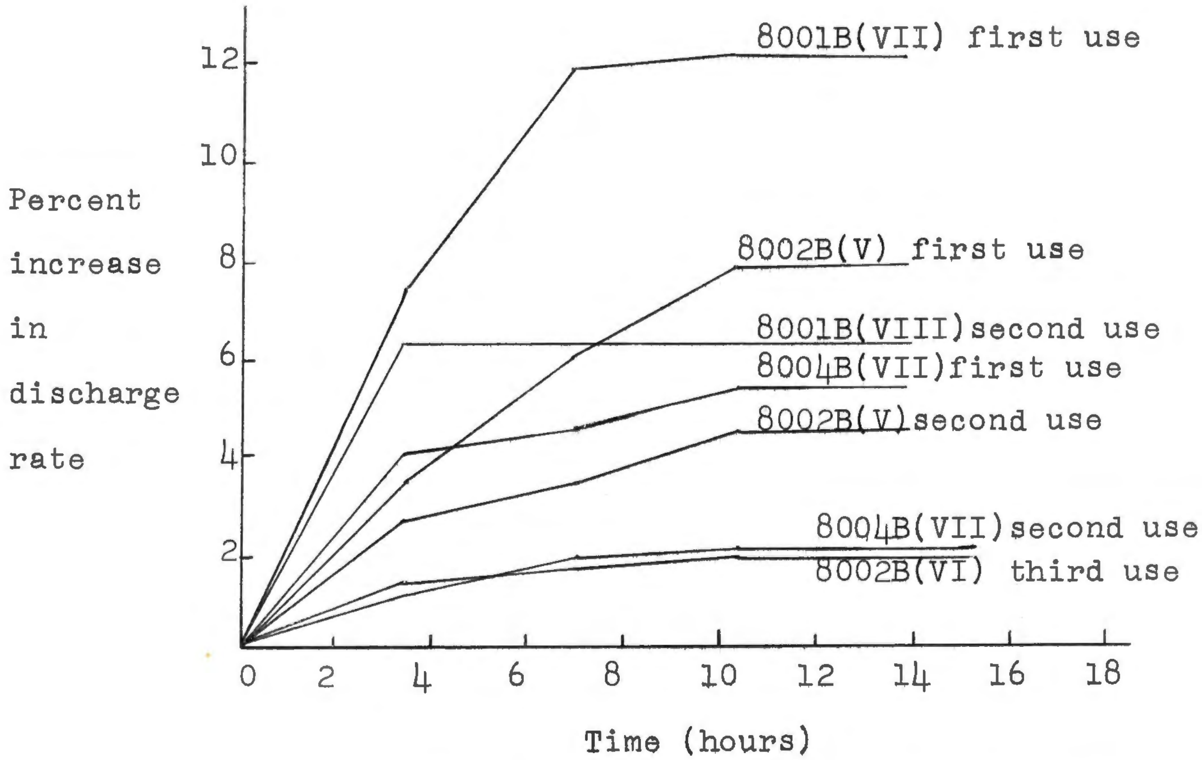

Figure 16. Average percentage change in discharge rate of nozzles at 40 psi, were tested with one pound fluometuron in five gallons of water. The 8001 brass wear test VII, 8002 brass wear test V, and 8004 brass wear test VII were tested in first use. The 8001 brass wear test VIII, 8002 brass wear test V and 8004 brass wear test VIII were tested in second use, and the 8002 brass wear test VI was tested in third use.

No attempt was made to evaluate differences between the results of the tests made with trifluralin, diuron and fluometuron mixtures. No common basis for comparing test results was found.

CHAPTER V

CONGLUSIONS

This study was conducted to determine the change in nozzle tips discharge capacity, using different concentration of trifluralin, diuron and fluometuron as spray materials. Different types and sizes of new nozzle tips were used. Also some previously used nozzle tips were tested. The amount of increase in nozzle discharge capacity ranged from -0.26 for nylon nozzle tips to a maximum of 19.41 percent for brass nozzle tips.

The increase in the discharge capacity of the brass nozzle tips was associated with the higher concentration of the diuron mixture.

The brass nozzle tips were much more susceptible to wear and increased their discharge capacity more rapidly than the hardened stainless steel nozzle tips.

The nylon nozzle tips showed a slight decrease in its original capacity.

The smaller size brass nozzle tips were more affected in their initial and total increase in discharge capacity than the larger size brass nozzle tips.

The abrasiveness of emulsion, liquid suspension and wettable powder, was reduced with the continuous recirculation of the spray mixture.

In general, the increase of discharge capacity characteristic of brass nozzle tips decreased at small rate with continuous fresh mixture.

I. SUGGESTIONS FOR FURTHER STUDIES IN THIS AREA

1. A study should be made to determine whether or not foreign material in the water supply influences the increase of nozzle tips discharge capacity.
2. A study should be made to determine whether or not the nozzle strainer affect its discharge capacity during operation.
3. A study should be made to determine whether or not the nozzle tips position on the discharge boom affect its discharge capacity.

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APPENDIX

TABLE II

WEAR TEST I, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE. SPRAY MIXTURE: TRIFLURALIN, 0.5 POUND AND WATER TO MAKE FIVE GALLONS

Nozzle No.	Before use		After use of:			
			3.5 hours	7 hours	10.5 hours	14 hours
	ml/min	gpm	Percent increase	Percent increase	Percent increase	Percent increase
8002B-1	790	0.209	0.00	1.26	1.26	1.26
8002B-2	800	0.211	1.25	1.25	1.25	1.25
8002B-3	810	0.214	0.00	0.00	0.61	0.61
Total	2400	0.634	1.25	2.51	3.12	3.12
Average	800	0.211	0.37	0.87	1.25	1.25
8003B-1	1183	0.312	0.25	0.59	0.59	0.59
8003B-2	1195	0.316	0.00	0.00	0.42	0.42
8003B-3	1183	0.312	0.59	1.01	1.01	1.01
Total	3561	0.941	0.84	1.60	2.02	2.02
Average	1187	0.314	0.25	0.50	0.67	0.67

TABLE III

WEAR TEST II, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE. SPRAY MIXTURE: DIURON DL, 0.44 POUND PLUS WATER TO MAKE SEVEN GALLONS

Nozzle No.	Before use ml/min	Before use gpm	After use of: 3.5 hours Percent increase	7 hours Percent increase	10.5 hours Percent increase	14 hours Percent increase	17.5 hours Percent increase	21 hours Percent increase
8002B31	800	0.211	2.50	5.00	6.25	6.25	6.87	6.87
8002B32	805	0.213	2.48	4.34	5.59	5.59	6.83	6.83
8002B33	805	0.213	1.86	3.70	4.34	4.96	5.59	5.59
Total	2410	0.637	6.84	13.04	16.18	16.80	19.29	19.29
Average	803	0.212	2.36	4.35	5.47	5.60	6.47	6.47
8003B41	1180	0.312	0.85	1.69	3.81	5.08	5.93	5.93
8003B42	1180	0.317	3.39	2.54	4.23	5.08	5.93	5.93
8003B43	1195	0.317	1.25	3.76	4.60	5.43	6.27	6.27
Total	3555	0.939	5.49	7.99	12.64	15.59	18.13	18.13
Average	1185	0.313	1.26	3.20	4.20	5.23	6.07	6.07

TABLE IV

WEAR TEST III, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE. SPRAY MIXTURE: DIURON DL, 1.05 POUNDS AND WATER TO MAKE FIVE GALLONS

Nozzle No.	Before use		After use of:					
			3.5 hours	7 hours	10.5 hours	14 hours	17.5 hours	21 hours
	ml/min	gpm	Percent increase	Percent increase	Percent increase	Percent increase	Percent increase	Percent increase
8001B51	430	0.114	4.18	9.30	12.79	16.27	18.60	18.60
8001B52	400	0.106	8.25	12.50	15.00	17.50	20.00	20.00
8001B53	390	0.103	6.41	12.82	15.38	17.43	19.74	19.74
Total	1220	0.322	18.57	34.62	43.17	51.20	58.34	58.34
Average	407	0.107	6.14	11.30	14.25	16.95	19.41	19.41
8002B31	855	0.226	4.44	6.43	7.13	8.18	11.11	11.11
8002B32	860	0.227	6.04	7.56	10.46	10.81	12.79	12.79
8002B33	850	0.225	5.05	5.88	8.23	9.41	10.58	10.58
Total	2565	0.678	15.53	19.87	25.82	28.40	34.48	34.48
Average	855	0.226	5.14	6.66	8.65	9.47	11.46	11.46

TABLE V

WEAR TEST IV, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE. SPRAY MIXTURE: DIURON DL, 0.44 POUND PLUS WATER TO MAKE SEVEN GALLONS

Nozzle No.	Before use ml/min	Before use gpm	After use of: 3.5 hours Percent increase	7 hours Percent increase	10.5 hours Percent increase	14 hours Percent increase	17.5 hours Percent increase
8001B71	390	0.103	7.69	10.25	12.82	15.38	15.38
8001B72	430	0.114	4.65	6.98	8.13	9.32	9.32
8001B73	400	0.116	5.00	7.50	10.00	10.00	10.00
Total	1220	0.322	17.34	24.73	30.95	34.70	34.70
Average	407	0.108	5.65	8.11	10.07	11.30	11.30
8003B61	1170	0.309	1.71	2.56	3.42	3.85	3.85
8003B62	1180	0.312	5.08	5.08	6.78	6.78	6.78
8003B63	1190	0.314	4.02	5.04	5.88	6.32	6.32
Total	3540	0.935	10.81	12.68	16.08	16.95	16.95
Average	1180	0.312	3.64	4.24	5.33	5.68	5.68

TABLE VI

WEAR TEST X, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE. SPRAY MIXTURE: DIURON DL, 0.44 POUND PLUS WATER TO MAKE SEVEN GALLONS

Nozzle No.	Before use		After use of: 3.5 hours	7 hours	10.5 hours	14 hours	17.5 hours
	ml/min	gpm	Percent increase	Percent increase	Percent increase	Percent increase	Percent increase
131 8002HSS	785	0.207	0.64	0.64	0.64	0.64	0.64
132 8002HSS	780	0.206	0.64	1.54	1.54	1.54	1.54
133 8002HSS	810	0.214	0.74	0.86	0.86	0.86	0.86
Total	2375	0.627	2.02	3.04	3.04	3.04	3.04
Average	792	0.209	0.63	1.01	1.01	1.01	1.01
8004B141	1546	0.408	2.20	4.85	6.47	6.79	8.41
8004B142	1586	0.419	2.52	4.22	5.67	6.24	8.01
8004B143	1533	0.405	1.11	4.76	5.67	7.17	8.48
Total	4665	1.232	5.83	13.83	17.81	20.00	24.90
Average	1555	0.411	1.93	4.63	5.92	6.57	8.30

Observation: The pump was changed at the end of the test because of severe leak.

TABLE VII

WEAR TEST XI, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE. SPRAY MIXTURE: DIURON DL, 1.05 POUNDS PLUS WATER TO MAKE FIVE GALLONS

Nozzle No.	Before use ml/min	Before use gpm	After use of: 3.5 hours Percent increase	7 hours Percent increase	10.5 hours Percent increase	14 hours Percent increase
8003B41	1250	0.330	7.44	8.00	9.60	9.60
8003B42	1250	0.330	5.84	7.20	8.48	8.48
8003B43	1270	0.335	5.51	7.09	9.84	9.84
Total	3770	0.959	18.79	22.29	27.92	27.92
Average	1257	0.332	6.20	7.40	9.31	9.31
8004B141	1667	0.443	4.89	7.40	8.59	8.59
8004B142	1713	0.453	5.25	7.41	8.41	8.41
8004B143	1663	0.439	5.41	6.43	7.03	7.03
Total	5052	1.335	15.55	21.24	24.03	24.03
Average	1684	0.449	5.17	7.07	8.02	8.02

TABLE VIII

WEAR TEST XII, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE. SPRAY MIXTURE: DIURON DL, 1.05 POUNDS PLUS WATER TO MAKE FIVE GALLONS

Nozzle No.	Before use		After use of:				
			3.5 hours	7 hours	10.5 hours	14 hours	17.5 hours
	ml/min	gpm	Percent increase	Percent increase	Percent increase	Percent increase	Percent increase
8002B151	870	0.230	4.60	6.90	10.34	10.34	10.34
8002B152	760	0.201	3.95	7.89	10.52	11.84	11.84
8002B153	780	0.206	8.97	10.26	12.82	15.38	15.38
Total	2410	0.637	17.52	25.05	33.68	37.56	37.56
Average	803	0.212	5.85	8.34	11.21	12.45	12.45
8003B161	1160	0.306	3.45	8.62	9.48	10.34	10.34
8003B162	1190	0.314	3.36	5.88	8.40	10.08	10.08
8003B163	1190	0.314	2.52	6.72	7.56	9.24	9.24
Total	3540	0.935	9.33	21.22	25.44	29.66	29.66
Average	1180	0.312	3.13	7.03	8.47	9.91	9.91

TABLE IX

WEAR TEST V, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE. SPRAY MIXTURE: FLUOMETURON, ONE POUND PLUS WATER TO MAKE FIVE GALLONS

Nozzle No.	Before use		After use of:			
	ml/min	gpm	3.5 hours Percent increase	7 hours Percent increase	10.5 hours Percent increase	14 hours Percent increase
8002B81	827	0.218	3.20	4.32	3.87	3.87
8002B82	810	0.214	4.69	8.27	8.64	8.64
8002B83	760	0.201	3.95	5.92	8.55	8.55
Total	2397	0.633	11.84	18.42	21.06	21.06
Average	799	0.211	4.00	6.13	8.01	8.01
8002B71	835	0.221	2.76	3.59	3.83	3.83
8002B72	830	0.219	2.17	3.01	5.42	5.42
8002B73	838	0.221	3.57	3.57	4.17	4.17
Total	2503	0.661	8.53	10.17	13.42	13.42
Average	834	0.220	2.87	3.47	4.67	4.67

TABLE X

WEAR TEST VI, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE. SPRAY MIXTURE: FLUOMETURON, ONE POUND PLUS WATER TO MAKE FIVE GALLONS

Nozzle No.	Before use		After use of:			
	ml/min	gpm	3.5 hours Percent increase	7 hours Percent increase	10.5 hours Percent increase	14 hours Percent increase
8002B81	885	0.234	0.79	2.82	2.82	2.82
8002B82	880	0.232	2.50	4.54	4.88	4.88
8002B83	825	0.218	0.34	4.24	4.24	4.24
Total	2590	0.684	3.63	11.60	11.94	11.94
Average	863	0.228	1.85	3.93	4.06	4.06
8002B71	867	0.229	3.94	3.94	3.94	3.94
8002B72	875	0.231	0.34	0.34	1.71	1.71
8002B73	873	0.231	1.37	1.37	1.72	1.72
Total	2615	0.691	5.65	5.65	7.37	7.37
Average	872	0.230	1.49	1.83	2.06	2.06

TABLE XI

WEAR TEST VII, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE. SPRAY MIXTURE: FLUOMETURON, ONE POUND PLUS WATER TO MAKE FIVE GALLONS

Nozzle No.	Before use		After use of:			
			3.5 hours	7 hours	10.5 hours	14 hours
	ml/min	gpm	Percent increase	Percent increase	Percent increase	Percent increase
8001B91	430	0.114	6.51	11.62	11.62	11.62
8001B92	383	0.101	9.13	11.74	12.27	12.27
8001B93	380	0.100	7.89	13.16	13.16	13.16
Total	1193	0.315	23.53	36.52	37.05	37.05
Average	398	0.105	7.53	12.06	12.31	12.31
8004B101	1533	0.405	3.27	4.15	5.67	5.67
8004B102	1571	0.415	3.50	4.39	5.03	5.03
8004B103	1583	0.418	4.55	5.24	5.49	5.49
Total	4687	1.238	11.77	13.74	16.19	16.19
Average	1562	0.413	4.09	4.60	5.44	5.44

TABLE XII

WEAR TEST VIII, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE. SPRAY MIXTURE: FLUOMETURON, ONE POUND PLUS WATER TO MAKE FIVE GALLONS

Nozzle No.	Before use		After use of:			
	ml/min	gpm	3.5 hours Percent increase	7 hours Percent increase	10.5 hours Percent increase	14 hours Percent increase
8001B91	480	0.127	4.17	4.17	4.17	4.17
8001B92	430	0.114	6.98	6.98	6.98	6.98
8001B93	430	0.114	6.98	6.98	6.98	6.98
Total	1340	0.355	18.13	18.13	18.13	18.13
Average	445	0.118	6.29	6.29	6.29	6.29
8004B101	1620	0.428	0.80	1.36	1.85	1.85
8004B102	1650	0.436	2.00	2.12	2.30	2.30
8004B103	1670	0.441	1.68	2.39	2.39	2.39
Total	4940	1.305	4.48	5.87	6.54	6.54
Average	1647	0.435	1.46	1.94	2.18	2.18

TABLE XIII

WEAR TEST IX, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE. SPRAY MIXTURE: FLUOMETURON, ONE POUND PLUS WATER TO MAKE FIVE GALLONS

Nozzle No.	Before use		After use of: 3.5 hours	7 hours	10.5 hours	14 hours
	ml/min	gpm	Percent increase	Percent increase	Percent increase	Percent increase
111 8002HSS	740	0.195	0.40	1.35	1.35	1.35
112 8002HSS	820	0.217	0.61	1.22	1.22	1.22
113 8002HSS	820	0.217	0.61	1.22	1.83	1.83
Total	2380	0.629	1.62	3.79	4.40	4.40
Average	793	0.209	0.63	1.26	1.51	1.51
12NF121	800	0.211	0.00	0.00	0.00	0.00
12NF122	783	0.207	-0.89	-0.89	-0.77	-0.77
12NF123	735	0.194	0.00	0.00	0.00	0.00
Total	2318	0.612	-0.89	-0.89	-0.77	-0.77
Average	773	0.204	-0.13	-0.13	-0.26	-0.26

VITA

Alberto C. Febre was born in Tunas, Oriente, Cuba, on August 9, 1915. He was educated in the elementary schools of that city and was graduated from Holguin High School, Cuba, in 1939. In 1940, he entered the Havana University, receiving a degree of Agronomic Engineer, in October, 1944. He worked in the Bureau of Agricultural Machinery, Ministry of Agriculture, Cuba, for sixteen years. In 1959, he moved to the United States and was enrolled as Instructor in the University of Puerto Rico, where he is member of the Department of Agricultural Engineering. In August, 1967, he entered the Graduate School of The University of Tennessee, on sabbatical leave from the University of Puerto Rico. He is married to the former Astrid Vallmajo from Sagua la Grande, Cuba, and he has a daughter and a son.