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THE ABRASIVE EFFECT OF WETTABLE POWDER HERBICIDES
ON SPRAYER NOZZLE ORIFICE TIPS

A Thesis
Presented to
the Graduate Council of
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In Partial Fulfillment
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Master of Science

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R. K. Patel

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I dedicate this literature to my parents, by whose efforts and inspiration I have attained my educational goal.

ABSTRACT

A weed is an undesirable plant which competes with crops for water, light, and mineral nutrients. The use of chemical herbicides is a successful method of weed control, however, the herbicide must be applied accurately and efficiently. A wettable powder herbicide has low solubility in a liquid medium. The insoluble nature of this material presents two problems of abrasion and agitation. The abrasive effect of the wettable powder can cause wear in the spraying system components. The objectives of this study were to determine the abrasive effect of wettable powder herbicides: atrazine and nitralin, in varying concentrations on different sizes of brass, hardened stainless steel, and nylon nozzle orifice tips, and with relation of hours of use.

The discharge capacity of each nozzle tips were measured on a nozzle calibration apparatus before each wear test. The nozzle tips were rechecked at intervals of 3.5 hours of use to determine the percentage change in the discharge capacity. In this study, 33 brass and 12 hardened stainless steel nozzle tips of four different sizes: 8001,

8002, 8003, and 8004, and nine nylon nozzles of two different sizes: 12NF and 20NF, were tested using several concentrations of atrazine and nitralin as the wettable powder herbicides.

The increase in the discharge capacity of the brass and hardened stainless steel nozzle tips was caused by the wear characteristics of the wettable powder. The amount of increase in nozzle discharge capacity ranged from 0.00 per cent for stainless steel to 27.65 per cent for brass nozzles. The increase in the discharge capacity of brass and hardened stainless steel nozzle tips was more during the first few hours of use, and was directly related to the concentration of the spray material. The brass nozzle tips had received greater and more rapid wear compared to the hardened stainless steel nozzle tips. The abrasive effect of the spray mixture was more severe on the smaller size nozzle tips as compared to the larger ones. With equal concentration, nitralin was more abrasive than was atrazine. Nylon nozzles showed a range of 1.47 to 5.71 per cent decrease in the discharge capacity.



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CHAPTER I

THE PROBLEM

I. INTRODUCTION

In his agricultural pursuits, from the earliest periods of his existence, man has had to contend with undesirable plants. Such plants, which are often prolific, persistent and interfere with agricultural operations, are known as weeds. Weeds compete with crops for water, light, and mineral nutrients. They increase the cost of labor and equipment, impair the quality of farm products and reduce the quantity and quality of livestock products. Weeds harbor insect and fungus pests that attack crop plants. They also cause depreciation of land values. Certain poisonous weeds impair the health of livestock and human beings.

The control of weeds is one of the important practices in modern farm management. Many methods of weed control have been devised; a recent successful method involves the use of herbicides. The use of herbicides for weed control

has more than doubled between 1959 and 1963 in the United States, and new chemicals and application equipment are being developed at a fast rate (5).¹ Many different kinds of chemicals available for use in controlling weeds are available in granular, wettable powder and liquid formulations. Several factors may affect the acceptance and use of chemicals and application equipment. These factors include the adjustment and care of the equipment, the mixing and agitation of spray mixture and the calibration of the application equipment.

For mechanical weed control, Beatty (2) reported that the labor requirements of the Mississippi cotton grower range from twenty to forty-one man-hours per acre. The use of herbicides in cotton, however, reduced the labor requirements to five man-hours per acre, and also increased cotton yields, resulting in an average financial gain of twenty-one dollars per acre. The United States Department of Agriculture has estimated that the average annual loss caused by weeds in the United States is five billion dollars (1).

¹The numbers appearing in parantheses refer to similarly numbered references in the Bibliography.

King (10) has stated that about 85 million acres in crops were treated with herbicides in 1961, costing 90 million dollars for chemicals alone.

Hendrickson (9) said,

In the summer of 1960, 280 meetings and demonstrations were organized in Western Canada to assist farmers and dealers in the proper adjustment and calibration of their sprayers, in order that they would be able to obtain more uniform and economical coverage. In many instances it was found that nozzles were so badly worn and/or damaged that it was impossible to adjust the sprayer to produce a uniform discharge. These findings confirmed the fact that farmers needed some guidance in the replacement of nozzle tips.

II. STATEMENT OF THE PROBLEM

The application of a herbicide involves two problems: the selection of the proper herbicide and the equipment to apply such material accurately and efficiently. A high rate of application of some materials not only wastes expensive chemicals, but may kill or injure the crops; a low rate of application will fail to achieve the desired control of weeds. The herbicides must be applied at the optimum rate.

At a constant speed and pressure, the even application of a spray mixture at optimum rate depends upon the accurate discharge capacity of the spray nozzles. The discharge

capacity of a nozzle is determined by the size of the nozzle orifice tip and the operating pressure. Any operating condition which causes a change in the nozzle orifice size will result in a related change in the nozzle orifice discharge capacity. In agricultural sprayer use, several factors can cause this change in nozzle orifice size. One contributing factor is the use of wettable powder herbicides. The wettable powder spray mixture consists of a material of low solubility in a liquid medium. The insoluble nature of this material presents two problems of abrasion and agitation. The abrasive action of the wettable powder can cause wear in the components of the spraying equipment. A second factor, relating to nozzle orifice size change, is the material from which the nozzle orifice tip is made. If a soft material is used, the abrasive action of the wettable powder mixture can cause a large increase in discharge capacity of the nozzle tip as compared with a harder nozzle tip material.

A knowledge of the abrasive characteristics of a wettable powder mixture is necessary for proper design and utilization of the agricultural sprayer.

III. OBJECTIVES OF THE STUDY

The objectives of this study were to determine:

1. The abrasive effect of a wettable powder spray mixture on the nozzle discharge capacity as related to varying concentration of the chemical.
2. The abrasive effect of a wettable powder spray mixture on the nozzle discharge capacity as related to brass, hardened stainless steel, and nylon nozzle tips.
3. The abrasive effect of a wettable powder spray mixture on the nozzle discharge capacity as related to the size of the nozzle orifice tip.
4. The abrasive effect of a wettable powder spray mixture on the nozzle discharge capacity as related to total hours of use.
5. The abrasive effect of 2-chloro-4-ethylamino-6-isopropylamino-s-triazine (atrazine) and 4-(methylsulfonyl)-2, 6-dinitro-N, N-dipropylaniline (nitralin) wettable powder spray mixtures on the nozzle discharge capacity.

CHAPTER II

REVIEW OF LITERATURE

The abrasive effect of some spray mixtures can cause wear on sprayer components such as the nozzle, pump and valves. Thus, accurate calibration is difficult if nozzle discharge capacity continuously changes. Abrasive mixtures such as those from wettable powders can cause nozzles to wear rapidly. If abrasive mixtures are used, wear-resistant nozzle tips and frequent calibration are necessary.

In the preliminary report on a project to evaluate the performance of spraying systems brass nozzles of 65 degree spraying angle with the application rate of 0.067 gpm, Hendrickson (9) stated that the average increase in discharge, at 50 hour intervals, was 2.78 per cent, 5.70 per cent, 0.86 per cent, 2.07 per cent, 1.12 per cent, and 0.96 per cent. A spray solution of 2,4-Dichlorophenoxyacetic Acid (2,4-D) mixed at the rate of one ounce per gallon of water was used.

Wylie and Boyce (12) conducted an experiment on nozzles made of brass, hardened stainless steel and nylon, using wettable powder herbicides for abraison and agitation

tests. The hardened stainless steel nozzle tips showed the lowest increase of discharge capacity. This increase in discharge capacity was 0.6 per cent compared with an increase of 6.9 per cent and 4.1 per cent for two brass nozzles of the same size, after 3.5 hours. The spray mixture of two pounds active ingredient of atrazine in 20 gallons of water was used. After 3.5 hours of use, with the same concentration of atrazine in other tests, the results showed a 1.3 per cent increase for hardened stainless steel as compared with 6.3 per cent and 5.2 per cent for two brass tips of the same size. After a total of 10.5 hours, a group of nylon nozzle tips showed an increase of 0.03 per cent discharge capacity, and a second group having a different size of nozzle, revealed a decrease in nozzle discharge of 3.6 per cent.

Dumas (4) conducted an experiment on nozzle orifice wear. The results showed 8.0 per cent, 7.0 per cent, and 3.0 per cent flow increase for FS 7-80° brass, aluminum and stainless steel nozzles, respectively. One pound of active 3-(3,4-Dichlorophenyl)-1,1-Dimethylurea (diuron DW) in 25 gallons of water was sprayed for 10 hours through the nozzles at 40 psi.

Doll, Knake, and Butler (3), after their recent study on the effects of wear on nozzle tips, suggested that brass nozzle tips be replaced after each tip has been used for spraying about 100 acres.

Wooten, Parker and Holstun (11) conducted an experiment to study the wear of spray nozzles, using a concentrate of 1.6 pounds of diuron DW and one pint of surfactant in 25 gallons of water. The results showed that the flow increase because of wear in the brass nozzles was approximately 19.0 per cent after only 18 hours of spraying at 30 psi, whereas, that of the stainless steel nozzle was only about 4.0 per cent. The wear of the chrome-plated brass nozzle was negligible after the first hour of spraying.

Gunkel (7) stated that prolonged use of the wettable powder spray materials caused a rounding of the suspended particles. This rounding of the particles reduced the abrasive characteristics of the material.

Dumas (4) also reported that the spray mixture should be drained from the tank to prevent the particles from wearing smooth because of continuous recirculation. At the same time, Doll, Knake, and Butler (3) stated that the output

increased at a greater rate when the nozzle orifice tips were first used than after they had had some wear.

CRANES-CREST

CHAPTER III

EXPERIMENTAL PROCEDURE

I. TEST EQUIPMENT

Wear Test Apparatus

The equipment used for conducting the wear tests was a laboratory spray apparatus. The tank, consisting of a 55-gallon drum, cut in half horizontally, was mounted in an angle iron frame. The inlet of the pump was connected to a 50-mesh stainless steel suction strainer by three-quarter-inch hose and three-quarter-inch pipe. This suction strainer was placed in the bottom of the tank.

The pump used in this spray apparatus was a Delavan, Model 7-2110 with a Ni-Resist alloy body, and plate and rotor with seven large nylon rollers. The rotor had seven equally-spaced slots, containing rollers which acted as vanes to force the liquid through the annular gap between the rotor and eccentric housing. Since hydraulic and centrifugal forces kept the rollers in contact with the housing, displacement was semi-positive, and capacity was roughly

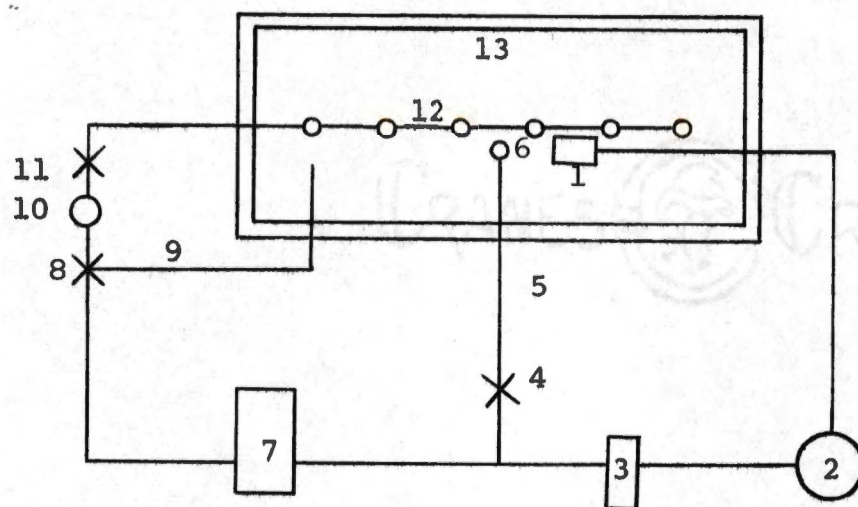
proportional to pump speed. The capacity of the pump was 10.7 gpm at 50 psi with 450 rpm.

A three-quarter-horsepower electric motor was used to supply the power for the pump. A V-belt drive between the motor and the pump, reduced the 1750 rpm of the motor to 440 rpm at the pump.

The discharge of the pump was connected to a line strainer containing a 50-mesh screen. To obtain a steady pressure, a small surge tank was located in the line, following the line strainer, to smooth out fluctuations of pressure. The flow diagram of the system is shown in Figure 1.

On the pressure side of the pump, a line with a valve was located between the line strainer and the surge tank to serve as a hydraulic agitation. This hydraulic agitator consisted of two Spraying Systems No. 6290 jet agitators, each with three No. 2 orifice tips, placed in the bottom of the tank for hydraulic agitation.

A Spraying System Company No. 8460 Diaphragm pressure relief valve was located between the surge tank and the boom. This valve was used to obtain the desired pressure at the nozzles on the boom. A by-pass line returned the excess liquid to the tank. A pressure gauge and a valve was located



1. Suction Strainer
2. Pump
3. Line Strainer
4. Valve
5. Hydraulic Agitator Line
6. Jet Agitator
7. Surge Tank
8. By-pass Pressure Regulator Valve
9. By-pass Line
10. Pressure Gauge
11. Valve
12. Six-nozzle Boom
13. Tank

Figure 1. Schematic Diagram of Wear Test Apparatus.

between the pressure relief valve and the boom on the same line. A boom with six nozzle bodies was located over the tank so the sprayed mixture could be collected in the tank and recirculated.

Nozzle Calibration Apparatus

A nozzle calibration apparatus was used to measure the discharge capacity of the nozzles before and after the wear tests. A fixture was connected with the city water system, through a Spraying System Company No. 6815 pressure relief valve and a pressure gauge. A standard nozzle body was located on the fixture to hold the nozzle orifice tip. A 2000 ml graduated cylinder was used to collect the discharge over a period of time. An electric clock was used to measure the time of discharge.

II. TEST MATERIALS

Nozzles

The nozzle is one of the key parts in the agriculture sprayer because it controls the spray application rate and the uniformity of the application of spray on the surface to be treated. The wear on the nozzle orifice can result in a change in the application rate.

Nozzles used for applying herbicide are classified by their spray delivery patterns, their discharge rate, and the material from which they are made. These delivery patterns are (a) fan, (b) solid cone, (c) hollow cone (8). Fan type nozzles are also classified according to the angle of the delivery pattern. These classifications apply to the nozzle tip because this part of the nozzle determines the type and volume of spray. The nozzle orifice tips are interchangeable and are easily replaced. The flat fan spray nozzle is best suited for the application of herbicides because they control spray particle size with the minimum driftage. Such nozzle spray patterns overlap in boom spraying to give uniform overall coverage.

For this study, the flat fan type nozzle orifice tips were made of three different materials, brass, hardened stainless steel, and nylon. The brass and hardened stainless steel nozzle orifice tips were manufactured by the Spraying System Company, Bellwood, Illinois. The size of nozzle orifice tips was marked by the manufacturing company indicating their discharge capacities at 40 psi, such as 8001. The first two digits 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 40 psi. In this study, the 8001, 8002, 8003, and 8004 sizes of brass and hardened stainless steel nozzle orifice tips were used.

The nylon nozzles were manufactured by the Century Engineering Corporation, Cedar Rapids, Iowa. The size of nylon orifice tips was marked by the company with a number such as 12NF. The number 12 indicates 12 gallons output per acre application, "N" indicates nylon tip, and "F" indicates the fan type for broadcast pattern of spraying. The output was based on one nozzle each 20 inches apart, at 40 psi, with 4 MPH speed. The 12NF and 20NF sizes of nylon nozzles were used in this study. Each nozzle tip was marked for individual identification.

Atrazine

Atrazine, a product of Geigy Agricultural Chemicals, is a wettable powder containing 80 per cent active ingredient. The solubility of atrazine in water is 70 ppm at 27°C temperature. It is light tan in color, odorless, has relatively low mammalian toxicity, and is recommended as a nonselective herbicide for weed control on railroads, storage yards, and

along highways. It is well established as a selective herbicide for the control of most annual broad-leaved weeds and grasses in Zea mays (corn), Saccarum officinarum (sugarcane), etc. It could be used as a preemergence, emergence, or early postemergence herbicide, at rates as high as eight pounds of active ingredient per acre. The normal rate of atrazine varies from 2.5 to 5 pounds in 20 to 40 gallons of water per acre. In this study, the atrazine was used at four different concentrations: (1) 1.25 pounds of atrazine in 10 gallons of water, (2) 1.25 pounds in 7.5 gallons of water, (3) 1.25 pounds in 5 gallons of water, and (4) 2.5 pounds in 5 gallons of water.

Nitralin

Nitralin, a product of Shell Chemical Company, containing 75 per cent active ingredient is also a wettable powder. It is yellow in color and contact with it during application would not be hazardous. It is recommended as a selective herbicide for the preemergence control of annual grasses and broad-leaved weeds in Glycine max (soybean) and Gossypium species (cotton), at rates as high as 1.5 pounds of wettable powder per acre on a broadcast basis. The normal

rate of nitralin varies from 0.75 to 1.5 pounds in 15 to 20 gallons of water per acre. In this study, the nitralin was used at three different concentrations: (1) 0.89, (2) 1.33, and (3) 2.66 pounds of nitralin in 10 gallons of water. For both the herbicides, the concentrations were chosen to get maximum wear on the nozzle orifice tips with maximum applicable concentration to the field.

III. TEST PROCEDURES

Nozzle Calibration

To calibrate the nozzle orifice tips, the following procedure was adopted:

The nozzle orifice tip was placed in the nozzle body on the nozzle calibration apparatus. The water was turned on and the pressure was adjusted to 40 psi by the pressure regulator valve. The 2000 ml graduated cylinder was placed under the nozzle to collect the discharge. An electric timer was used to measure the time. The discharge of the nozzle was collected for one minute. At the end of the time period, the cylinder was removed and the amount of water collected was recorded. This procedure was repeated three times. The conversion factor of one milliliter per minute is equal to

0.0002642 gallon per minute was used to convert the test data to gallon per minute.

Nozzle Wear Test

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

All nozzle tips were checked for the discharge capacities on the nozzle calibration apparatus before they were used for wear tests.

The wettable powder was mixed with the required quantity of water in the tank. In this study, the required quantity of water varried from 5 to 10 gallons. The pump was run for 15 minutes to mix the solution thoroughly. Then the nozzle tips and 50-mesh nozzle strainers were placed in the nozzle bodies on the boom of the wear test apparatus. Two different groups, of three nozzles each, were tested each time. The pressure at the nozzles was adjusted to 40 psi, using the pressure regulator valve, and was maintained at the same pressure throughout the test period. After three and one-half hours, the pump was stopped and the nozzle orifice tips were removed and rechecked on the nozzle calibration apparatus, to determine the change in the discharge capacity caused by wear. The results of this

recalibration were recorded to compare with the initial discharge of the same nozzle orifice tips. Such tests were continued on a three and one-half hour base, using the same mixture and nozzle tips, until two successive tests showed no change in discharge capacity.

CHAPTER IV

DISCUSSION OF RESULTS

Atrazine and nitralin wettable powder herbicides were used as the spray material for the wear tests at several concentrations as indicated in Chapter III. Thirty-three brass nozzle tips of 8001, 8002, 8003, and 8004 sizes; twelve hardened stainless steel of 8001, 8002, 8003, and 8004 sizes; and nine nylon nozzle tips of 12NF and 20NF sizes were tested for wear characteristics. The discharge capacity of each nozzle tip was measured before and after a three-and-one-half hour test interval. Maximum test period was twenty-one hours. The spray material and nozzle tips were replaced after each wear test.

Tests Using Atrazine

Six wear tests were completed using atrazine as the spray material, on twenty-one brass nozzle tips of 8001, 8002, 8003, and 8004 sizes; nine hardened stainless steel nozzle tips of 8001, 8002, and 8003 sizes; and six nylon nozzle tips of 12NF and 20NF sizes, a total of thirty-six nozzle tips.

In wear test I, three 8004 brass nozzle tips and three 20NF nylon nozzle tips were tested. The concentration was 1.25 pounds atrazine in 10 gallons of water. The wear test was run for a total of 14 hours. The results of the test are shown in Figure 2. The complete wear test data are located in Table II of the Appendix.

The average increase in the discharge capacity of 8004 brass nozzle tips was 1.05 per cent. The average decrease in the discharge capacity of 20NF nylon nozzle tips was 1.47 per cent. There was no additional change in discharge capacity after 7 hours for either types of nozzle tips.

Wear tests II and III were run for a period of 17.5 hours with a concentration of 1.25 pounds atrazine in 7.5 gallons of water. In wear test II, three 8003 brass nozzle tips and three 8003 hardened stainless steel nozzle tips were tested. In wear test III, three 8001 brass nozzle tips and 8004 brass nozzle tips were tested. The results of these wear tests are shown in Figure 3. The complete wear test data are located in Tables III and IV of the Appendix.

The average increase in the discharge capacity of 8001, 8003, and 8004 brass nozzle tips was 9.60 per cent, 6.60 per cent, and 2.61 per cent, respectively. The average increase

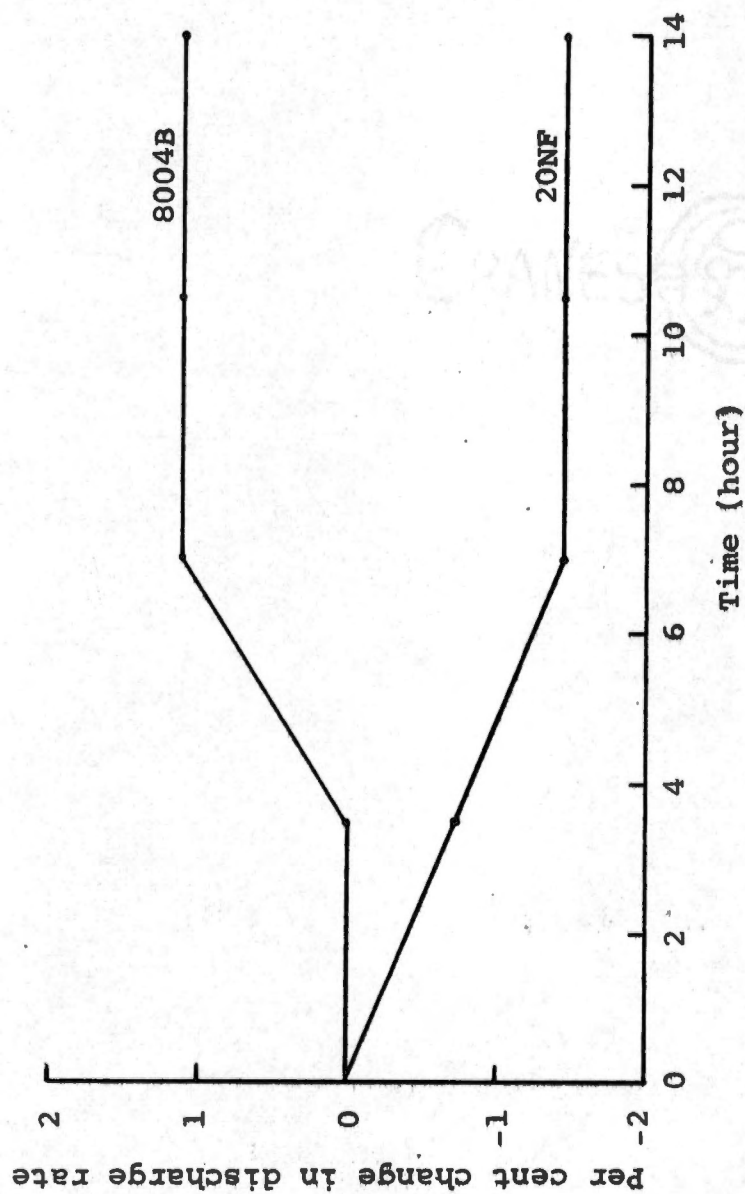


Figure 2. Average percentage change in discharge rate of 8004 brass and 20NF nylon nozzles. The spray mixture of 1.25 pounds of atrazine in 10 gallons of water was run at 40 psi.

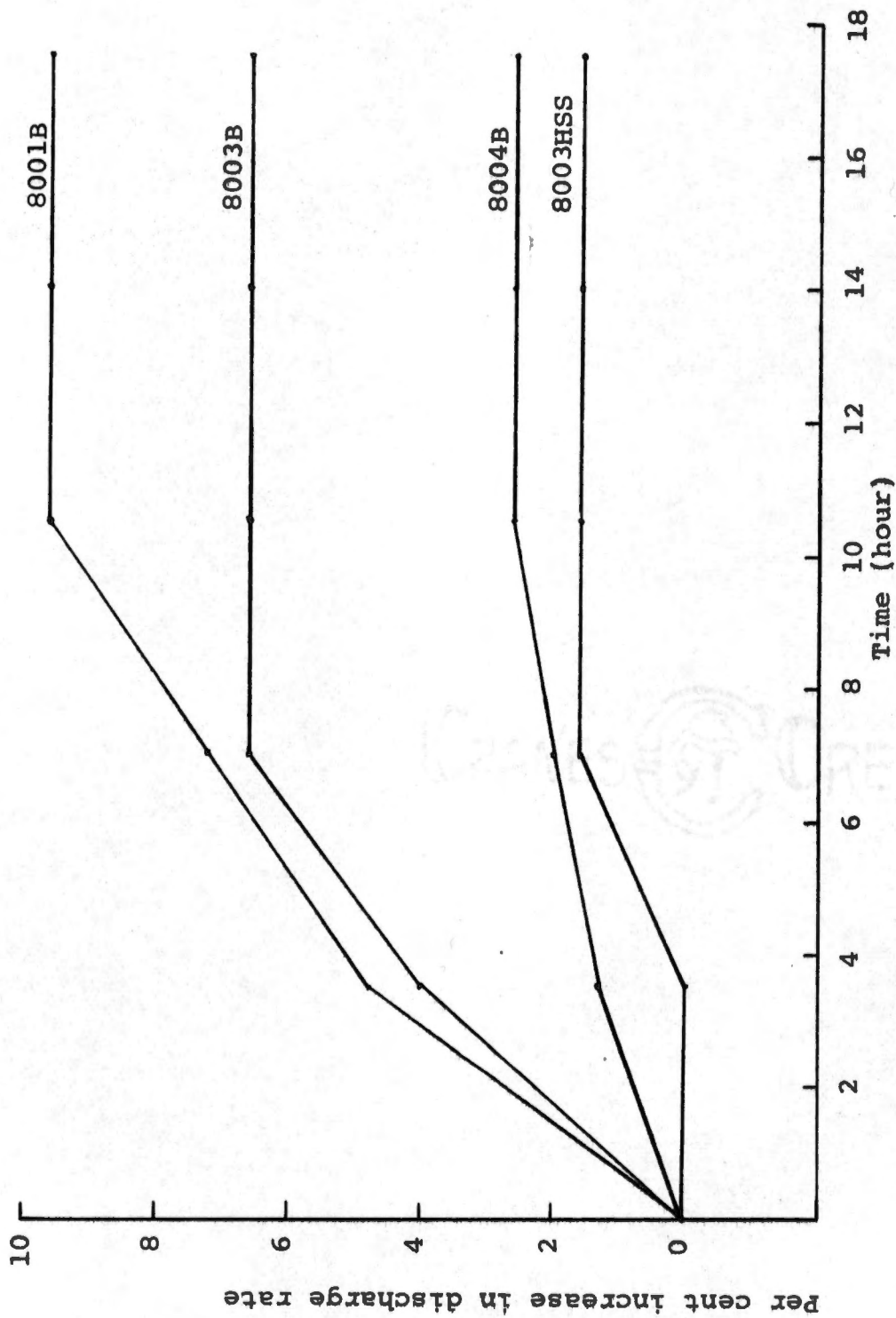


Figure 3. Average percentage increase in discharge rate of 8001, 8003, 8004 brass and 8003 hardened stainless steel nozzles. The spray mixture of 1.25 pounds of atrazine in 7.5 gallons of water was run at 40 psi.

in the discharge capacity of the 8003 hardened stainless steel was 1.96 per cent. In wear test II, the 8003 brass and 8003 hardened stainless steel nozzle tips showed no increase in the discharge capacity after 7 hours of use. In wear test III, the 8001 and 8004 brass nozzle tips showed no increase in the discharge capacity after 10.5 hours of use.

In wear test IV, three 8002 hardened stainless steel nozzle tips and three 12NF nylon nozzle tips were tested. The concentration used in this test was 1.25 pounds of atrazine in 5 gallons of water. This wear test was run for a total of 14 hours. The results are shown in Figure 4. The complete test data are located in Table V of the Appendix.

An average increase in the discharge capacity of the 8002 hardened stainless steel nozzle tips was 1.23 per cent after 7 hours of use, and an average decrease in the discharge capacity of 12NF nylon nozzles was 4.19 per cent after 3.5 hours of use.

In wear test V, three 8001 and three 8002 brass nozzle tips were tested with 5 pounds of atrazine in 10 gallons of water as the spray material. In wear test VI, three 8003 brass and three 8001 hardened stainless steel nozzle tips

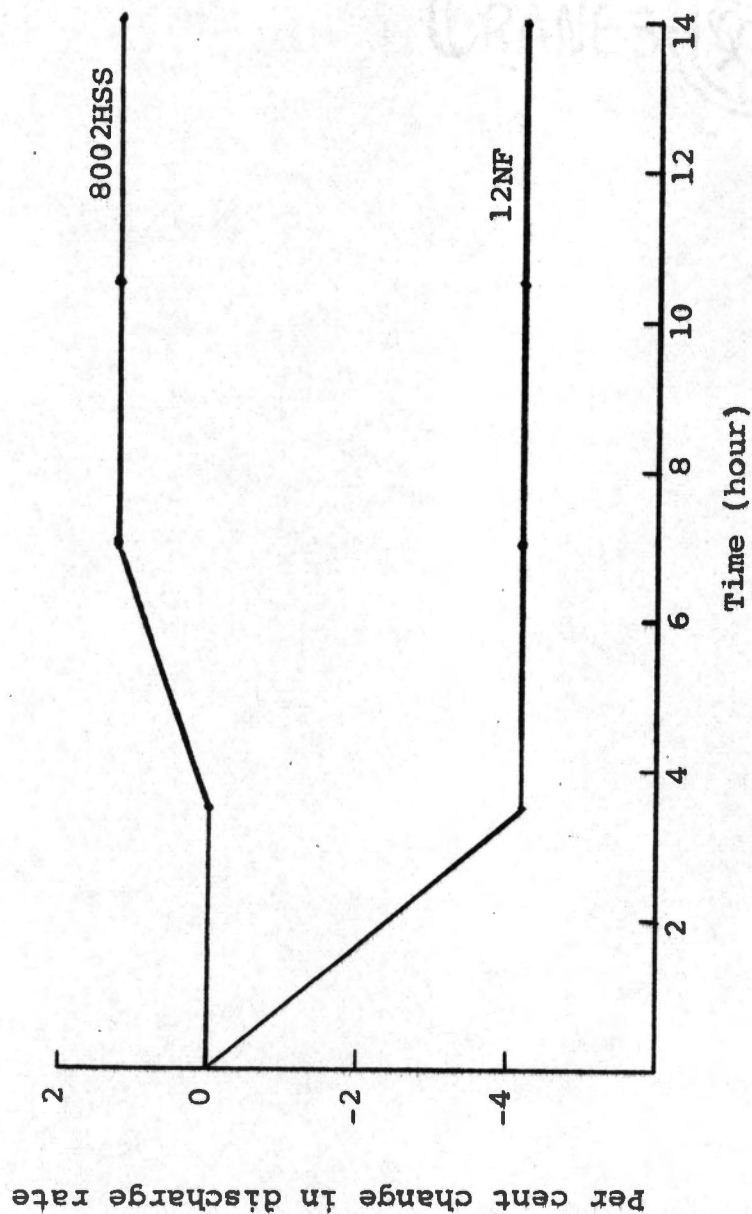


Figure 4. Average percentage change in discharge rate of 8002 hardened stainless steel and 12NF nylon nozzles. The spray mixture of 1.25 pounds of atrazine in 5 gallons of water was run at 40 psi.

were tested with the same mix-ratio of the spray material used in wear test V. The actual concentration used in wear test VI was 2.5 pounds of atrazine in 5 gallons of water. Wear test V was run for a total period of 21 hours, whereas wear test VI was run for 17.5 hours. The results of both tests are shown in Figure 5. The complete wear test data are located in Tables VI and VII of the Appendix.

After 3.5 hours of use, the average increase in the discharge rate of the 8001, 8002, and 8003 brass nozzle tips was 14.64 per cent, 10.14 per cent, and 7.35 per cent, respectively. The 8001 hardened stainless steel nozzle tips showed no increase in the discharge capacity until after 7 hours of use. After 14 hours of use, the average increase in the discharge rates of the 8001 and 8002 brass nozzle tips was 27.65 per cent and 18.61 per cent, respectively. The 8003 brass and 8001 hardened stainless steel nozzle tips showed an increase in discharge capacity of 12.44 per cent and 5.50 per cent, respectively, after 10.5 hours of use.

Tests Using Nitralin

Three wear tests were completed using nitralin at three different concentrations as indicated in Chapter III.

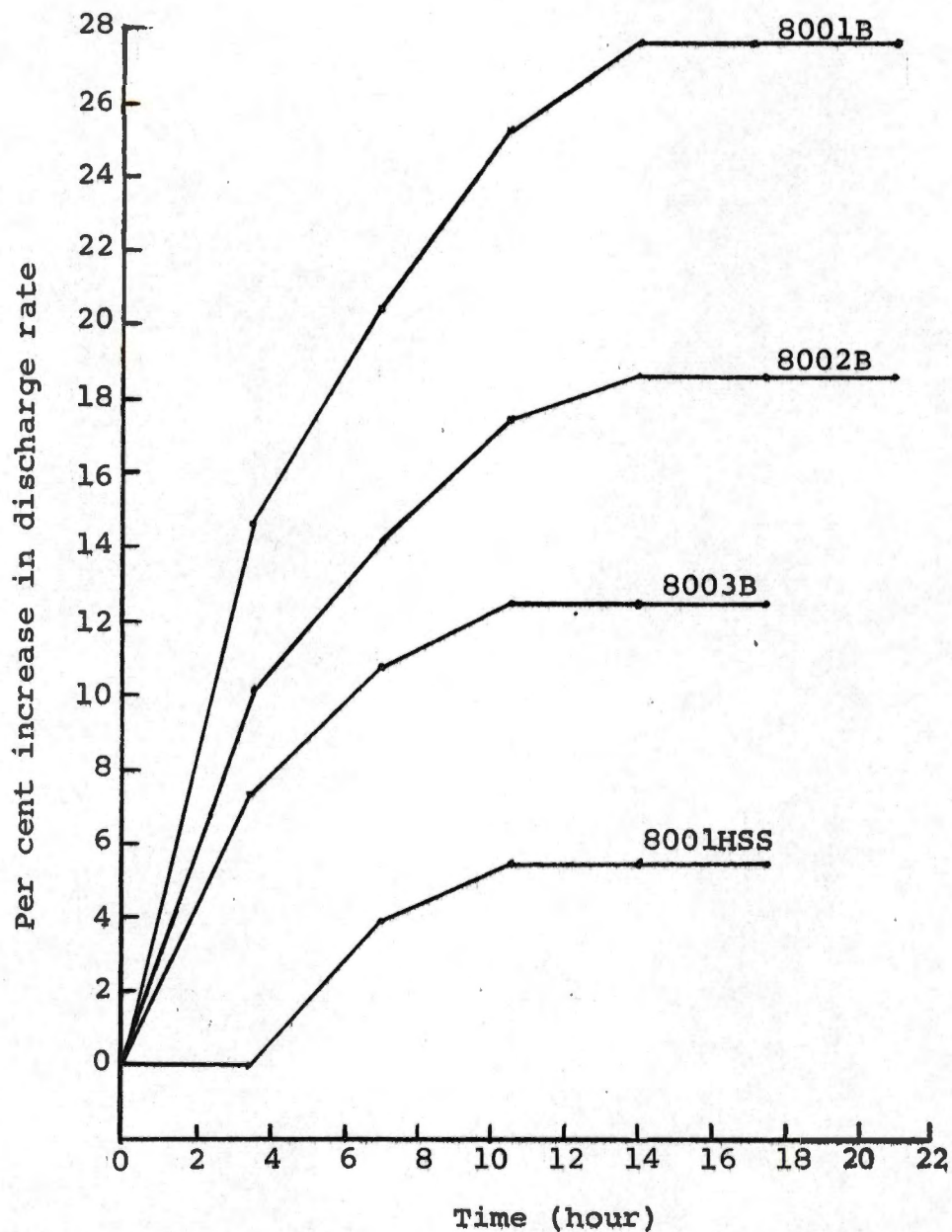


Figure 5. Average percentage increase in discharge rate of spray nozzles at 40 psi. The 8001 and 8002 brass nozzles were tested with 5 pounds of atrazine in 10 gallons of water. The 8003 brass and 8001 hardened stainless steel nozzles were tested with 2.5 pounds of atrazine in 5 gallons of water.

Twelve brass nozzle tips of 8001, 8002, 8003, and 8004 sizes, three hardened stainless steel nozzle tips of 8004 size, and three nylon nozzle tips of 12NF size were tested.

In wear test VII, three 8001 and three 8003 brass nozzle tips were tested with 0.89 pound of nitralin in 10 gallons of water. The results of this test are shown in Figure 6. The complete wear test data are located in Table VIII of the Appendix.

After 3.5 hours of use, the 8001 and 8003 brass nozzle tips showed an increase of 7.44 per cent and 5.11 per cent in the discharge capacity, respectively. The 8001 and 8003 brass nozzle tips showed an increase of 12.40 per cent and 6.82 per cent, respectively, after 10.5 hours of use, in the discharge capacity. There was no additional change in the discharge capacity after 10.5 hours of use. The small size brass nozzle tips showed higher initial wear and also higher total wear compared with the larger size nozzle tips.

In wear test VIII, three 8002 brass and three 12NF nylon nozzle tips were tested with 1.33 pounds of nitralin in 10 gallons of water, as the spray material, for a total of 21 hours. The results of this test are shown in Figure 7. The complete wear test data are located in Table IX of the Appendix.

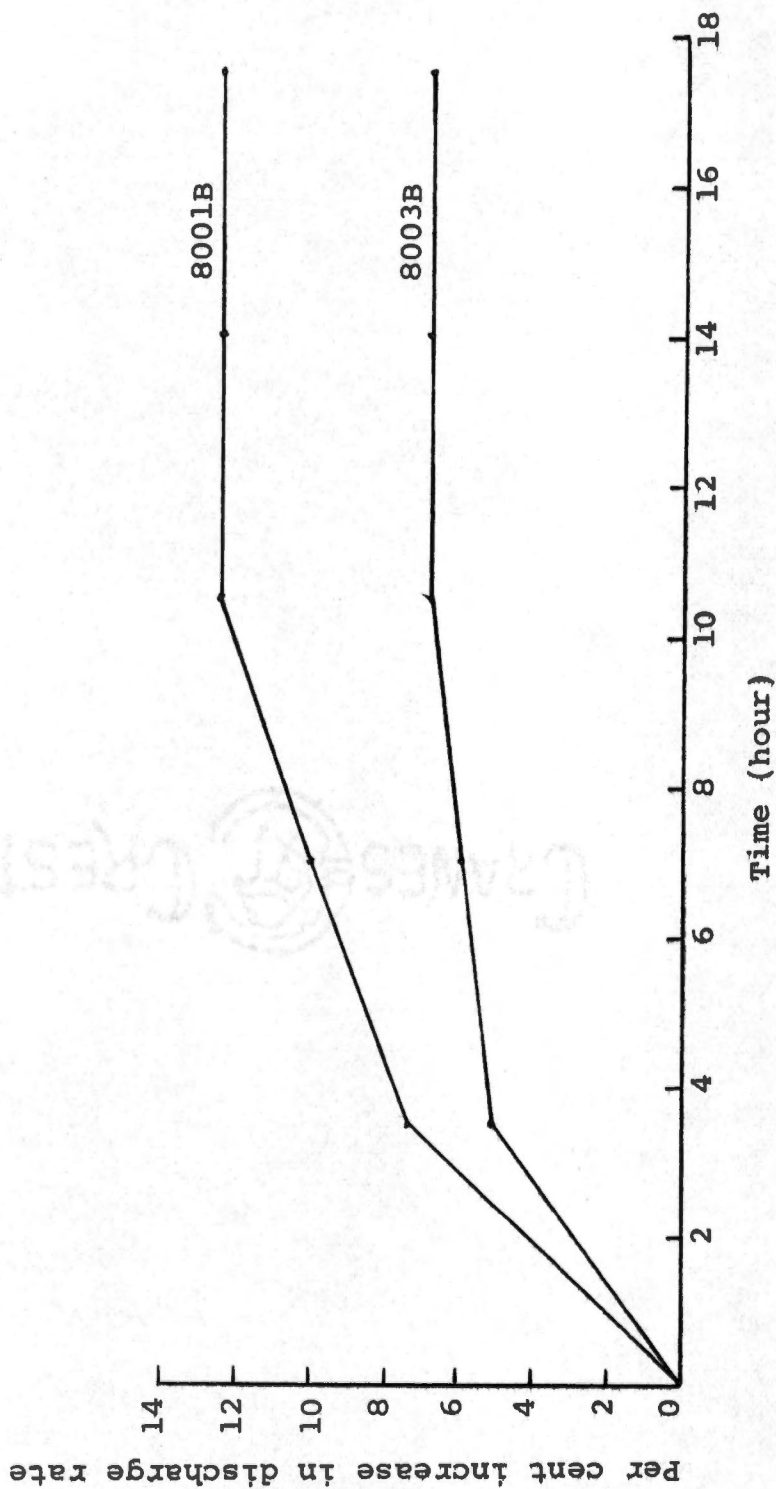


Figure 6. Average percentage increase in discharge rate of 8001 and 8003 brass nozzles. The spray mixture of 0.89 pound of nitralin in 10 gallons of water was run at 40 psi.

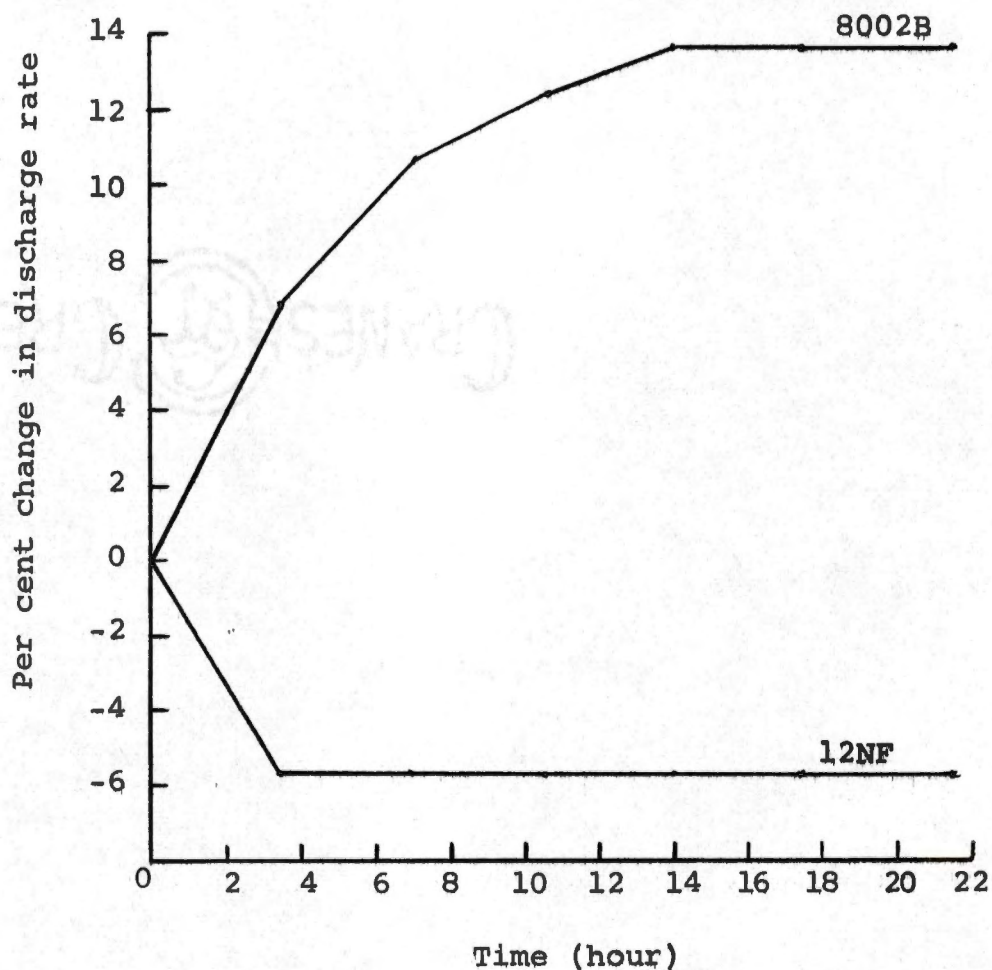


Figure 7. Average percentage change in discharge rate of 8002 brass and 12NF nylon nozzles. The spray mixture of 1.33 pounds of nitralin in 10 gallons of water was run at 40 psi.

The 12NF nylon nozzle tips showed an average decrease of 5.71 per cent in the discharge capacity after 3.5 hours of use, and showed no change in the discharge capacity after that period. The 8002 brass nozzle tips showed an average increase of 6.84 per cent, 10.68 per cent, 12.39 per cent, and 13.67 per cent in the discharge capacity at an interval of 3.5 hours of use. There was no additional change in the discharge capacity after 14 hours of use.

The higher concentration of nitralin was used in wear test IX, to determine the wear characteristics on the three 8004 brass and three 8004 hardened stainless steel nozzle tips. The concentration used in this test was 2.66 pounds of nitralin in 10 gallons of water. The wear test was run for a total of 17.5 hours. The results of the wear test are shown in Figure 8. The complete wear test data are located in Table X of the Appendix. The 8004 hardened stainless steel nozzle tips showed no increase in the discharge capacity during the 17.5 hours test period. The 8004 brass nozzle tips showed an average increase of 3.72 per cent, 5.25 per cent, and 6.56 per cent in the discharge capacity, at the interval of 3.5 hours of use; they showed no change in the discharge capacity after 10.5 hours of use.

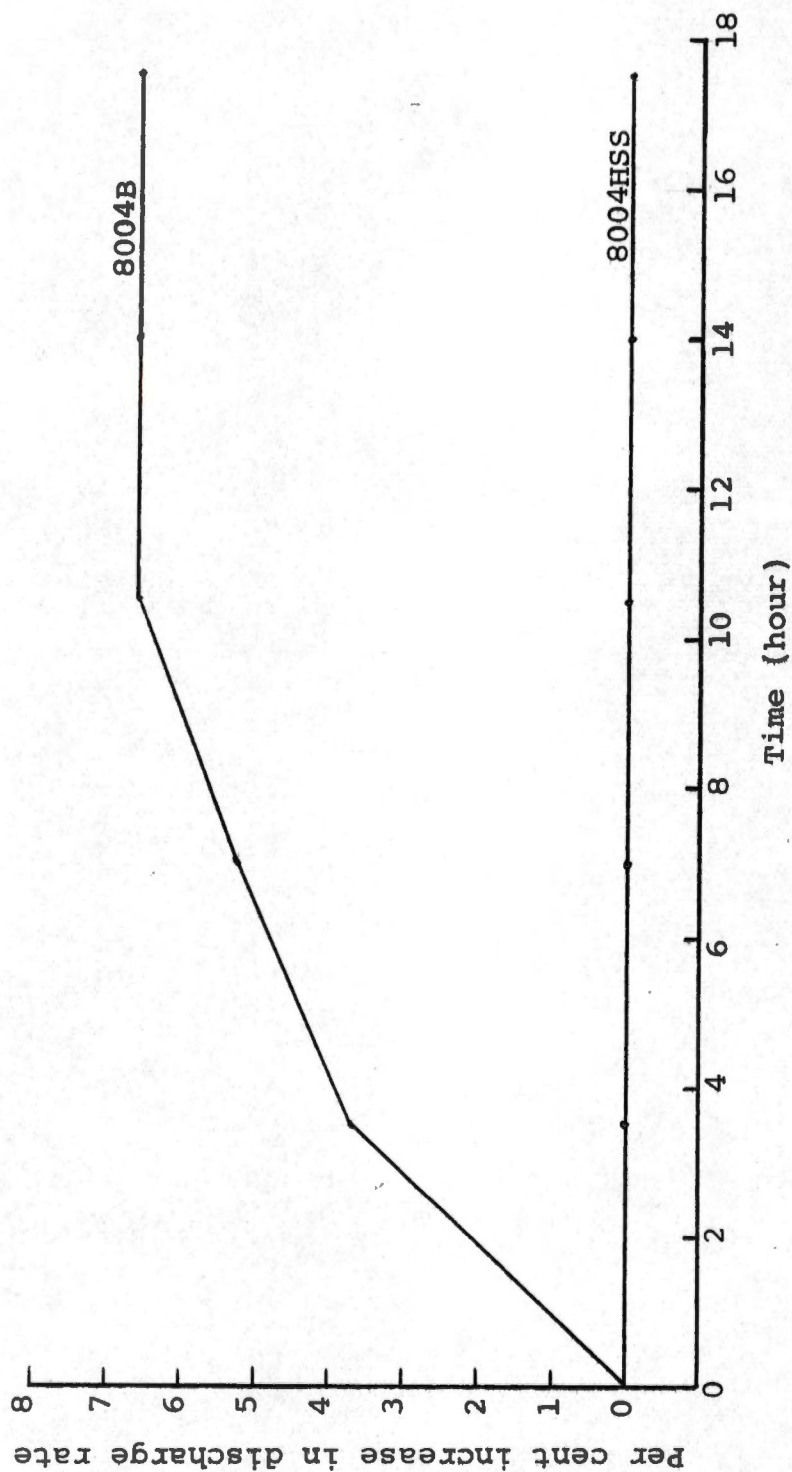


Figure 8. Average percentage increase in discharge rate of 8004 brass and 8004 hardened stainless steel nozzles. The spray mixture of 2.66 pounds of nitralin in 10 gallons of water was run at 40 psi.

Inter-relationship of Wear Characteristics

The wear characteristics in this study involved several factors: (1) time-period of use, (2) nozzle size, (3) nozzle type material, (4) inert material of wettable powder, and (5) concentration of the spray material.

The abrasive effect of wettable powder decreased with the prolonged use of the spray material. The increase in the discharge capacity, due to wear on the brass and hardened stainless steel nozzle tips, declined after their prolonged use. This is shown in Table I.

The abrasive effect of the wettable powder proved to be more severe on the smaller size brass nozzle tips when compared with the larger ones. This is shown in Figure 3, pg. 23. In wear test III, the abrasive increase in discharge of the 8001 brass nozzle tips, at 3.5-hour intervals, was 4.80 per cent, 7.20 per cent, and 9.60 per cent, whereas the average increase in discharge of 8004 brass nozzle tips, at 3.5-hour intervals, was 1.30 per cent, 1.96 per cent, and 2.61 per cent. The total increase in the discharge of the 8001 and 8004 brass nozzle tips was 9.60 per cent and 2.61 per cent, respectively, after 10.5 hours of use.

The abrasive effect of the wettable powder changed

TABLE I

AVERAGE PERCENTAGE INCREASE IN DISCHARGE RATE OF
 SPRAYER NOZZLES AT 3.5-HOUR INTERVALS AT 40 psi
 SPRAY MATERIALS; ATRAZINE AND NITRALIN

Wear Test No.	Nozzle Type	Average per cent 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
I	8004B	0.00	1.05	1.05	1.05	--
II	8003B	4.01	6.60	6.60	6.60	6.60
II	8003HSS	0.00	1.59	1.59	1.59	1.59
III	8001B	4.80	7.20	9.60	9.60	9.60
III	8004B	1.30	1.96	2.61	2.61	2.61
IV	8002HSS	0.00	1.23	1.23	1.23	--
V	8001B	14.64	20.38	25.20	27.65	27.65
V	8002B	10.14	14.90	17.36	18.61	18.61
VI	8003B	7.35	10.74	12.44	12.44	12.44
VI	8001HSS	0.00	3.93	5.50	5.50	5.50
VII	8001B	7.44	9.92	12.40	12.40	12.40
VII	8003B	5.11	5.97	6.82	6.82	6.82
VIII	8002B	6.84	10.68	12.39	13.67	13.67
IX	8004B	3.72	5.25	6.56	6.56	6.56
IX	8004HSS	0.00	0.00	0.00	0.00	0.00

with the type of nozzle material. The soft nozzle tips received heavy wear. In this study, the brass nozzle tips received higher initial and total wear compared with the hardened stainless steel nozzle tips of the same size. This is shown in Figure 3, pg. 23. The data are taken from the Table III of the Appendix.

In wear test II, the average increase in discharge of the 8003 brass nozzle tips, at 3.5-hour intervals, was 4.01 per cent and 6.60 per cent, whereas the average increase in the discharge of the 8003 hardened stainless steel nozzle tips, at 3.5-hour intervals, was 0.00 per cent, and 1.59 per cent. The total increase in the discharge capacity of the 8003 brass and 8003 hardened stainless steel nozzle tips was 6.60 per cent and 1.59 per cent, respectively, after 7 hours of use.

In this study, the discharge capacity of the nylon nozzles was reduced. There was more reduction in the discharge of the smaller size nylon nozzle tips when compared to the larger ones. This is shown in Figure 9. The data were taken from the Tables II, V, and IX of the Appendix.

In wear test IV, the 12NF nylon nozzle tips showed a 4.19 per cent decrease in the discharge rate, after 3.5 hours

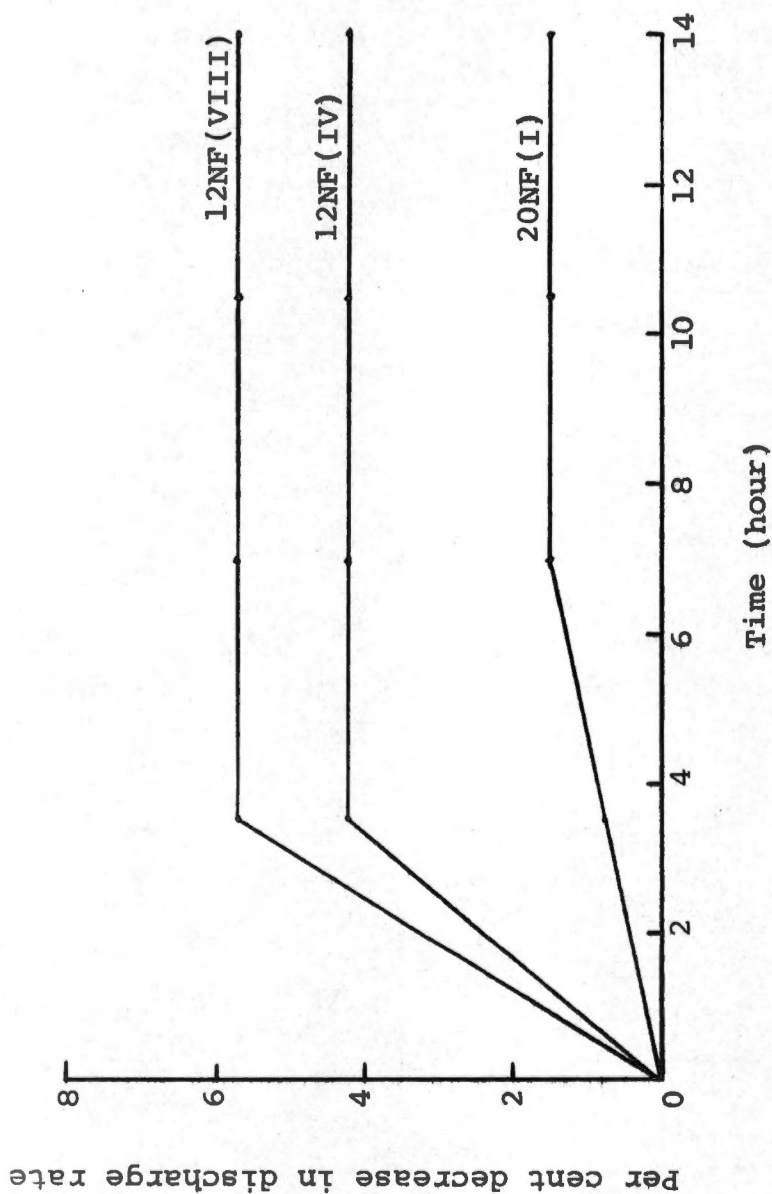


Figure 9. Average percentage decrease in discharge rate of nylon nozzles at 40 psi. The 12NF nozzles in Wear Test VIII and IV were tested with 1.33 pounds of nitralin in 10 gallons of water and 1.25 pounds of atrazine in 5 gallons of water, respectively. The 20NF nozzles were tested with 1.25 pounds of atrazine in 10 gallons of water.

of use, with 1.25 pounds of atrazine in 5 gallons of water. Nylon nozzle tips of the same size showed a 5.71 per cent decrease in the discharge rate after 3.5 hours of use, with 1.33 pounds of nitralin in 10 gallons of water in wear test I, the 20NF nylon nozzle tips showed an average decrease of 0.74 per cent and 1.47 per cent, at 3.5-hour intervals, with 1.25 pounds of atrazine in 10 gallons of water.

The inert material of the wettable powder may change the wear characteristics of the nozzle tips. Garton and Morgan (6) made the following statement: "It is generally agreed that wear and ultimate failure of spray pumps is caused by the inert material rather than by the active chemicals." The same inert ingredient can act on the spray nozzle tips. An attempt was made to verify this statement by comparing the results of the tests made with two different spray materials, atrazine and nitralin, on the same types of nozzle orifice tips. These data are found in Figure 10.

The average increase in the discharge capacity of the 8003 brass nozzle tips, at 3.5-hour intervals, was 4.01 per cent and 6.60 per cent, with 1.25 pounds of atrazine in 7.5 gallons of water used in wear test II. The average increase in the discharge capacity of the 8003 brass nozzle tips, at

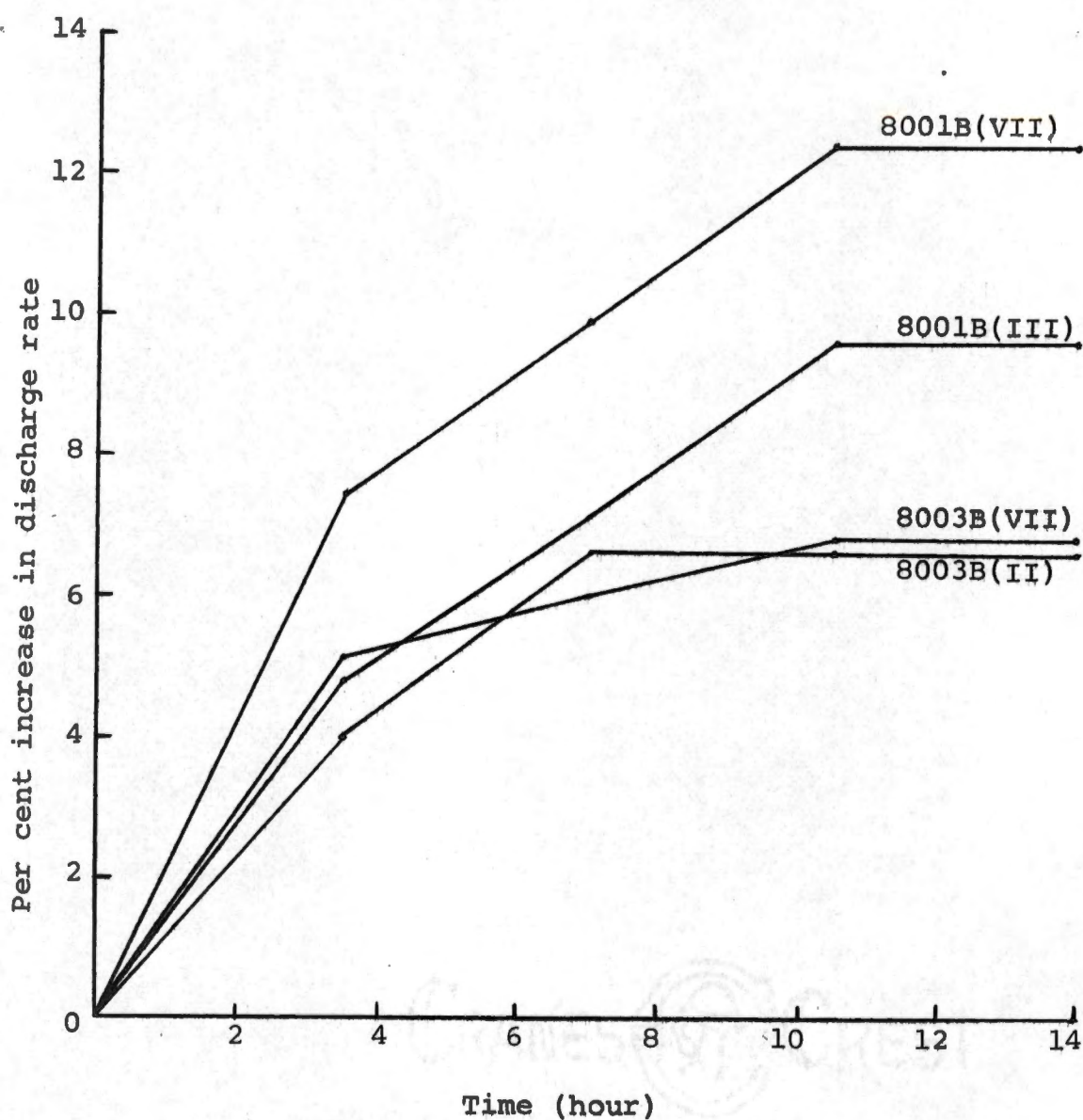


Figure 10. Average percentage increase in discharge rate of nozzles at 40 psi. The 8001 and 8003 brass nozzles were tested with 1.25 pounds of atrazine in 7.5 gallons of water in Wear Test III and II, respectively. The 8001 and 8003 brass nozzles in Wear Test VII were tested with 0.89 pound of nitralin in 10 gallons of water.

3.5-hour intervals, was 5.11 per cent, 5.97 per cent, and 6.82 per cent, with 0.89 pound of nitralin in 10 gallons of water, used in wear test VII. In wear test II, the total increase in the discharge of the 8003 brass nozzle tips was 6.60 per cent after 10.5 hours of use, whereas, with the low concentration of nitralin used in wear test VII, the total increase in the discharge of the same type of nozzle tips was 6.82 per cent, after the same period of use. The average increase in the discharge rate of the 8001 brass nozzle tips, at 3.5-hour intervals, was 4.80 per cent, 7.20 per cent, and 9.60 per cent, with 1.25 pounds of atrazine in 7.5 gallons of water used as the spray material in wear test III. The average increase in the discharge capacity of the 8001 brass nozzle tips, at 3.5-hour intervals, was 7.44 per cent, 9.92 per cent, and 12.40 per cent, with 0.89 pound of nitralin in 10 gallons of water, used as the spray material in the wear test VII. The total increase in the discharge of the 8001 brass nozzle tips, in wear test III was 9.60 per cent with atrazine, whereas the total increase in the discharge of the same type nozzle tips in wear test VII was 12.40 per cent with nitralin, after 10.5 hours of use.

The concentration of the spray material also changed

the wear characteristics. The higher concentration caused the higher initial and total wear on the smaller size nozzle tips compared to the larger tips. At the same time, the low concentration caused less wear on the larger size nozzle tips, when compared to the smaller ones. These are shown in Figure 11. The data were taken from the Tables II, IV, and VI of the Appendix.

In wear test V, the average increase in the discharge rate of the 8001 brass nozzle tips, at 3.5-hour intervals, was 14.64 per cent, 20.38 per cent, 25.20 per cent, and 27.65 per cent with 5 pounds of atrazine in 10 gallons of water as the highest concentration used in this study. In the same wear test, with the same spray material, the average increase in the discharge of the 8002 brass nozzle tips, at 3.5-hour intervals, was 10.14 per cent, 14.90 per cent, 17.36 per cent, and 18.61 per cent. Using the same concentration in wear test VI, the average increase in the discharge capacity of the 8003 brass nozzle tips, at 3.5-hour intervals, was 7.35 per cent, 10.74 per cent, and 12.44 per cent. The total increase in the discharge capacity of the 8001, 8002, and 8003 brass nozzle tips was 27.65 per cent, 18.61 per cent, and 12.44 per cent, respectively, after 14 hours of use.

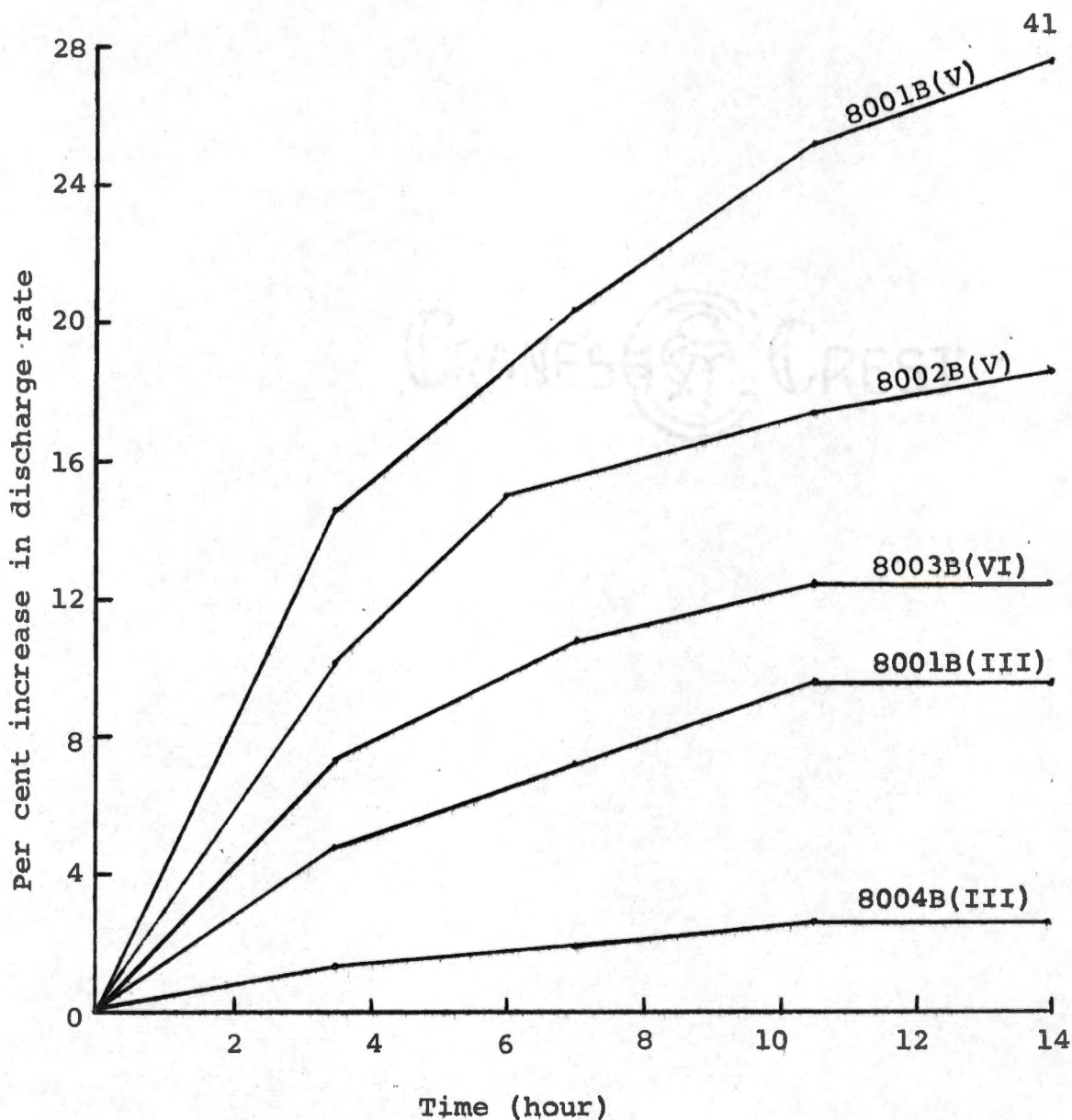


Figure 11. Average percentage increase in discharge rate of nozzles at 40 psi. The 8001 and 8002 brass nozzles in Wear Test I were tested with 5 pounds of atrazine in 10 gallons of water. The 8003 brass nozzles in Wear Test VI were tested with 2.5 pounds of atrazine in 5 gallons of water. The 8001 and 8004 brass nozzles in Wear Test III were tested with 1.25 pounds of atrazine in 7.5 gallons of water.

Using a low concentration, 1.25 pounds of atrazine in 7.5 gallons of water, in the wear test III, the average increase in the discharge of the 8001 brass nozzle tips, at 3.5-hour intervals, was 4.80 per cent, 7.20 per cent, and 9.60 per cent, whereas, in the same wear test, using the same spray material, the average increase in the discharge rate of the 8004 brass nozzle tips, at 3.5-hour intervals was 1.30 per cent, 1.96 per cent, and 2.61 per cent. The total increase in the discharge capacity of the 8001 and 8004 brass nozzle tips was 9.60 per cent and 2.61 per cent, respectively, after 10.5 hours of use.

CHAPTER V

CONCLUSIONS

In this study, four different sizes of 33 brass nozzle tips, four different sizes of 12 hardened stainless steel nozzle tips, and two different sizes of nine nylon nozzles, making a total of 54 nozzles, were tested using several concentrations of atrazine and nitralin as the wettable powder herbicides.

The increase in the discharge capacity of the brass and hardened stainless steel nozzle tips was caused by the wear characteristics of particles of the wettable powder. The amount of increase in nozzle discharge capacity ranged from 0.00 per cent to 27.65 per cent.

The increase in the discharge capacity of the nozzle tips resulting from wear was directly related to the concentration of the spray material. The abrasive effect of the wettable powder spray mixture on the nozzle tips was more severe with the higher concentration of the spray material.

The increase in the discharge capacity of the brass nozzle tips was greater and more rapid compared to that of

the hardened stainless steel nozzle tips. There was higher initial and total wear on the brass nozzle tips compared to the hardened stainless steel nozzle tips. No abrasive effect of wettable powder spray mixtures was observed in nylon nozzle tips.

The increase in the discharge rate of the brass and hardened stainless steel nozzle tips was inversely related to the size of the nozzle tips. The abrasive effect of wettable powder spray material was more severe on the smaller size nozzle tips, compared to that shown by the larger tips. The decrease in the discharge capacity of the nylon nozzles was inversely related to the size of the nozzle tips. There was more decrease in the discharge of the smaller size nylon nozzle tips, compared to the larger ones.

The abrasive effect of wettable powder spray material on the nozzle tips was more severe during the first few hours of use.

With equal concentration of pounds of formulation per gallon of water, nitralin was more abrasive on the same type and size of nozzle tips than was atrazine.

I. SUGGESTIONS FOR FURTHER STUDIES

IN THIS AREA

1. To get most accurate and practical results, spray materials should be changed as often as possible to lessen the rounding of the particles of the wettable powder spray material.
2. A study should be made to determine whether or not the temperature of the spray mixture influences the abrasive effect on nozzle orifice tip.
3. A study should be made to determine whether or not the spray patterns of the sprayer nozzles are changed with the change of their discharge rate.

BIBLIOGRAPHY



8. Hansen, C. M., B. H. Grigsby, and B. R. Churchill.
Weed Spraying Equipment. East Lansing, Michigan:
Michigan State University, Cooperative Extension
Service, Bulletin E-357, November, 1958, p. 11.
9. Hendrickson, M. F. "An Evaluation of Weed Sprayer
Nozzle Performance." Proceedings 19th Annual
Meeting North Central Weed Control Conference.
St. Paul, Minnesota, December 3, 4, 5, 1962, pp.
72-74.
10. King, L. J. Weeds of the World, Plant Science Mono-
graphs. New York: Interscience Publishers, Inc.,
1966, p. 349.
11. Wooten, O. B., R. E. Parker, and J. T. Holstun.
"Effects of Diuron on Wear of Spray Nozzles."
Report, United States Department of Agriculture,
Agricultural Research Service, ARS 42-91, Nov-
ember, 1963.
12. Wylie, M. L., and E. K. Boyce. "Wettable Powder
Herbicides--Problems with Abrasion and Agitation,"
Tennessee Farm and Home Science, April, May, June,
1962, Progress Report 42. Knoxville, Tennessee:
Agricultural Experiment Station, University of
Tennessee, April, May, June, 1962, pp. 10-11.

APPENDIX

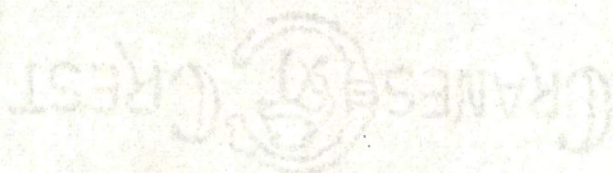


TABLE II

WEAR TEST I, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND
PERCENTAGE CHANGE IN DISCHARGE RATE AFTER USE.

SPRAY MIXTURE: ATRAZINE 80W, 1.25 POUNDS
+ 10 GALLONS WATER

Nozzle No.	Before use ml/min gpm		After use of											
			3.5 hours			7 hours			10.5 hours			14 hours		
			ml/min	gpm	% change	ml/min	gpm	% change	ml/min	gpm	% change	ml/min	gpm	% change
8004B-4	1520	0.402	1520	0.402	+0.00	1530	0.404	+0.66	1530	0.404	+0.66	1530	0.404	+0.66
8004B-5	1600	0.428	1600	0.428	+0.00	1620	0.428	+1.25	1620	0.428	+1.25	1620	0.428	+1.25
8004B-6	1600	0.428	1600	0.428	+0.00	1620	0.428	+1.25	1620	0.428	+1.25	1620	0.428	+1.25
TOTAL	4720	1.258	4720	1.258	+0.00	4770	1.260	+3.16	4770	1.260	+3.16	4770	1.260	+3.16
Average	1573	0.416	1573	0.416	+0.00	1590	0.420	+1.05	1590	0.420	+1.05	1590	0.420	+1.05
20NF-1	1360	0.359	1350	0.357	-0.74	1340	0.354	-1.47	1340	0.354	-1.47	1340	0.354	-1.47
20NF-2	1360	0.359	1350	0.357	-0.74	1340	0.354	-1.47	1340	0.354	-1.47	1340	0.354	-1.47
20NF-3	1350	0.357	1340	0.354	-0.74	1330	0.351	-1.48	1330	0.351	-1.48	1330	0.351	-1.48
TOTAL	4070	1.075	4040	1.068	-2.22	4010	1.059	-4.42	4010	1.059	-4.42	4010	1.059	-4.42
Average	1357	0.358	1347	0.356	-0.74	1337	0.353	-1.47	1337	0.353	-1.47	1337	0.353	-1.47

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: ATRAZINE 80W, 1.25 POUNDS

+ 7.5 GALLONS WATER

Nozzle No.	Before use ml/min gpm		After use of														
			3.5 hours			7 hours			10.5 hours			14 hours			17.5 hours		
			ml/min	gpm	% in-crease	ml/min	gpm	% in-crease	ml/min	gpm	% in-crease	ml/min	gpm	% in-crease	ml/min	gpm	% in-crease
8003B-1	1160	0.306	1200	0.317	3.45	1230	0.325	6.03	1230	0.325	6.03	1230	0.325	6.03	1230	0.325	6.03
8003B-2	1140	0.301	1180	0.312	3.51	1210	0.320	6.14	1210	0.320	6.14	1210	0.320	6.14	1210	0.320	6.14
8003B-3	1180	0.312	1240	0.328	5.08	1270	0.336	7.63	1270	0.336	7.63	1270	0.336	7.63	1270	0.336	7.63
TOTAL	3480	0.919	3620	0.957	12.04	3710	0.981	19.80	3710	0.981	19.80	3710	0.981	19.80	3710	0.981	19.80
Average	1160	0.306	1207	0.319	4.01	1237	0.327	6.60	1237	0.327	6.60	1237	0.327	6.60	1237	0.327	6.60
8003HSS-1	1260	0.333	1260	0.333	0.00	1280	0.338	1.59	1280	0.338	1.59	1280	0.338	1.59	1280	0.338	1.59
8003HSS-2	1290	0.341	1290	0.341	0.00	1310	0.346	1.55	1310	0.346	1.55	1310	0.346	1.55	1310	0.346	1.55
8003HSS-3	1230	0.325	1230	0.325	0.00	1250	0.330	1.63	1250	0.330	1.63	1250	0.330	1.63	1250	0.330	1.63
TOTAL	3780	0.999	3780	0.999	0.00	3840	1.014	4.77	3840	1.014	4.77	3840	1.014	4.77	3840	1.014	4.77
Average	1260	0.333	1260	0.333	0.00	1280	0.338	1.59	1280	0.338	1.59	1280	0.338	1.59	1280	0.338	1.59

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: ATRAZINE 80W, 1.25 POUNDS
+ 7.5 GALLONS WATER

Nozzle No.	Before use ml/min gpm		After use of														
			3.5 hours			7 hours			10.5 hours			14 hours			17.5 hours		
			ml/min	gpm	% in-crease	ml/min	gpm	% in-crease	ml/min	gpm	% in-crease	ml/min	gpm	% in-crease	ml/min	gpm	% in-crease
8001B-4	420	0.111	440	0.116	4.76	450	0.119	7.14	460	0.122	9.52	460	0.122	9.52	460	0.122	9.52
8001B-5	420	0.111	440	0.116	4.76	450	0.119	7.14	460	0.122	9.52	460	0.122	9.52	460	0.122	9.52
8001B-6	410	0.108	430	0.114	4.88	440	0.116	7.32	450	0.119	9.76	450	0.119	9.76	450	0.119	9.76
TOTAL	1250	0.330	1310	0.346	14.40	1340	0.354	21.60	1370	0.363	28.80	1370	0.363	28.80	1370	0.363	28.80
Average	417	0.110	437	0.115	4.80	447	0.118	7.20	457	0.121	9.60	457	0.121	9.60	457	0.121	9.60
8004B-1	1580	0.417	1600	0.423	1.27	1610	0.425	1.90	1620	0.428	2.53	1620	0.428	2.53	1620	0.428	2.53
8004B-2	1510	0.399	1530	0.404	1.32	1540	0.407	1.99	1550	0.410	2.65	1550	0.410	2.65	1550	0.410	2.65
8004B-3	1510	2.399	1530	0.404	1.32	1540	0.407	1.99	1550	0.416	2.65	1550	0.416	2.65	1550	0.416	2.65
TOTAL	4600	1.215	4660	1.231	3.91	4690	1.239	5.88	4720	1.248	7.83	4720	1.248	7.83	4720	1.248	7.83
Average	1533	0.405	1553	0.410	1.30	1563	0.413	1.96	1573	0.416	2.61	1573	0.416	2.61	1573	0.416	2.61

TABLE V

WEAR TEST IV, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND
PERCENTAGE CHANGE IN DISCHARGE RATE AFTER USE.

SPRAY MIXTURE: ATRAZINE 80W, 1.25 POUNDS
+ 5 GALLONS WATER

Nozzle No.	Before use ml/min gpm		After use of											
			3.5 hours			7 hours			10.5 hours			14 hours		
			ml/min	gpm	% change	ml/min	gpm	% change	ml/min	gpm	% change	ml/min	gpm	% change
8002HSS-1	790	0.209	790	0.209	+0.00	800	0.211	+1.26	800	0.211	+1.26	800	0.211	+1.26
8002HSS-2	820	0.217	820	0.217	+0.00	830	0.219	+1.22	830	0.219	+1.22	830	0.219	+1.22
8002HSS-3	840	0.222	840	0.222	+0.00	850	0.225	+1.20	850	0.225	+1.20	850	0.225	+1.20
TOTAL	2450	0.648	2450	0.648	+0.00	2480	0.655	+3.68	2480	0.655	+3.68	2480	0.655	+3.68
Average	817	0.216	817	0.216	+0.00	827	0.218	+1.23	827	0.218	+1.23	827	0.218	+1.23
12NF-1	700	0.185	670	0.177	-4.28	670	0.177	-4.28	670	0.177	-4.28	670	0.177	-4.28
12NF-2	750	0.198	720	0.191	-4.00	720	0.191	-4.00	720	0.191	-4.00	720	0.191	-4.00
12NF-3	700	0.185	670	0.177	-4.28	670	0.177	-4.28	670	0.177	-4.28	670	0.177	-4.28
TOTAL	2150	0.568	2060	0.545	-12.56	2060	0.545	-12.56	2060	0.545	-12.56	2060	0.545	-12.56
Average	717	0.189	687	0.182	-4.19	687	0.182	-4.19	687	0.182	-4.19	687	0.182	-4.19

TABLE VI

WEAR TEST V, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND
PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE.

SPRAY MIXTURE: ATRAZINE 80W, 5 POUNDS
+ 10 GALLONS WATER

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	ml/ min	gpm	% in- crease	ml/ min	gpm	% in- crease	ml/ min	gpm	% in- crease	ml/ min	gpm	% in- crease	ml/ min	gpm	% in- crease	ml/ min	gpm	% in- crease
8001B-1	410	0.108	470	0.124	14.63	500	0.132	21.95	520	0.137	26.80	530	0.140	29.27	530	0.140	29.27	530	0.140	29.27
8001B-2	400	0.106	460	0.122	15.00	480	0.127	20.00	500	0.132	25.00	510	0.135	27.50	510	0.135	27.50	510	0.135	27.50
8001B-3	420	0.111	480	0.127	14.28	500	0.132	19.20	520	0.137	23.80	530	0.140	26.19	530	0.140	26.19	530	0.140	26.19
TOTAL	1230	0.325	1410	0.373	43.91	1480	0.391	61.15	1540	0.406	75.60	1570	0.415	82.96	1570	0.415	82.96	1570	0.415	82.96
Average	410	0.108	470	0.124	14.64	493	0.130	20.38	513	0.135	25.20	523	0.138	27.65	523	0.138	27.65	523	0.138	27.65
8002B-1	820	0.217	910	0.240	10.95	950	0.251	15.85	970	0.254	18.30	980	0.259	19.51	980	0.259	19.51	980	0.259	19.51
8002B-2	780	0.208	860	0.227	10.28	900	0.238	15.70	920	0.243	17.99	930	0.246	19.23	930	0.246	19.23	930	0.246	19.23
8003B-3	760	0.209	830	0.219	09.20	860	0.227	13.15	880	0.232	15.80	890	0.235	17.10	890	0.235	17.10	890	0.235	17.10
TOTAL	2360	0.626	2600	0.686	30.43	2710	0.716	44.70	2770	0.731	52.09	2800	0.740	55.84	2800	0.740	55.84	2800	0.740	55.84
Average	787	0.209	867	0.229	10.14	903	0.239	14.90	923	0.244	17.36	933	0.247	18.61	933	0.247	18.61	933	0.247	18.61

TABLE VII

WEAR TEST VI, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND
PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE.

SPRAY MIXTURE: ATRAZINE 80W, 2.5 POUNDS

+ 5 GALLONS WATER

Nozzle No.	Before use ml/min gpm		After use of														
			3.5 hours			7 hours			10.5 hours			14 hours			17.5 hours		
			ml/min	gpm	% in-crease	ml/min	gpm	% in-crease	ml/min	gpm	% in-crease	ml/min	gpm	% in-crease	ml/min	gpm	% in-crease
8003B-4	1140	0.301	1220	0.322	7.02	1260	0.333	10.53	1280	0.338	12.28	1280	0.338	12.28	1280	0.338	12.28
8003B-5	1180	0.312	1280	0.338	8.48	1320	0.349	11.86	1340	0.354	13.56	1340	0.354	13.56	1340	0.354	13.56
8003B-6	1220	0.322	1300	0.343	6.56	1340	0.354	9.84	1360	0.359	11.48	1360	0.359	11.48	1360	0.359	11.48
TOTAL	3540	0.935	3800	1.003	22.06	3920	1.036	32.23	3980	1.051	37.32	3980	1.051	37.32	3980	1.051	37.32
Average	1180	0.312	1267	0.334	7.35	1307	0.345	10.74	1327	0.350	12.44	1327	0.350	12.44	1327	0.350	12.44
8001HSS-1	420	0.111	420	0.111	0.00	440	0.116	4.76	450	0.119	7.14	450	0.119	7.14	450	0.119	7.14
8001HSS-2	420	0.111	420	0.111	0.00	430	0.114	2.38	430	0.114	2.38	430	0.114	2.38	430	0.114	2.38
8001HSS-3	430	0.114	430	0.114	0.00	450	0.119	4.65	460	0.122	6.98	460	0.122	6.98	460	0.122	6.98
TOTAL	1270	0.336	1270	0.336	0.00	1320	0.349	11.79	1340	0.355	16.50	1340	0.355	16.50	1340	0.355	16.50
Average	424	0.112	424	0.112	0.00	440	0.116	3.93	447	0.118	5.50	447	0.118	5.50	447	0.118	5.50

TABLE VIII

WEAR TEST VII, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND
PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE.

SPRAY MIXTURE: NITRALIN, 0.89 POUND
+ 10 GALLONS WATER

Nozzle No.	Before use ml/min gpm		After use of														
			3.5 hours			7 hours			10.5 hours			14 hours			17.5 hours		
			ml/min	gpm	% in-crease	ml/min	gpm	% in-crease	ml/min	gpm	% in-crease	ml/min	gpm	% in-crease	ml/min	gpm	% in-crease
8001B-7	400	0.106	430	0.114	7.50	440	0.116	10.00	450	0.119	12.50	450	0.119	12.50	450	0.119	12.50
8001B-8	400	0.106	430	0.114	7.50	440	0.116	10.00	450	0.119	12.50	450	0.119	12.50	450	0.119	12.50
8001B-9	410	0.108	440	0.116	7.32	450	0.119	9.76	460	0.122	12.20	460	0.122	12.20	460	0.122	12.20
TOTAL	1210	0.320	1300	0.344	22.32	1330	0.351	29.76	1360	0.360	37.20	1360	0.360	37.20	1360	0.360	37.20
Average	403	0.107	433	0.115	7.44	443	0.117	9.92	453	0.120	12.40	453	0.120	12.40	453	0.120	12.40
8003B-7	1200	0.317	1260	0.333	5.00	1270	0.336	5.83	1280	0.338	6.66	1280	0.338	6.66	1280	0.338	6.66
8003B-8	1180	0.312	1240	0.328	5.08	1250	0.330	5.93	1260	0.333	6.78	1260	0.333	6.78	1260	0.333	6.78
8003B-9	1140	0.301	1200	0.317	5.26	1210	0.320	6.14	1220	0.322	7.02	1220	0.322	7.02	1220	0.322	7.02
TOTAL	3520	0.930	3700	0.978	15.34	3730	0.986	17.90	3760	0.993	20.46	3760	0.993	20.46	3760	0.993	20.46
Average	1173	0.310	1233	0.326	5.11	1243	0.329	5.97	1253	0.331	6.82	1253	0.331	6.82	1253	0.331	6.82

TABLE IX

WEAR TEST VIII, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND
PERCENTAGE CHANGE IN DISCHARGE RATE AFTER USE.

SPRAY MIXTURE: NITRALIN, 1.33 POUNDS
+ 10 GALLONS WATER

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		ml/ min	gpm	% change	ml/ min	gpm	% change	ml/ min	gpm	% change	ml/ min	gpm	% change	ml/ min	gpm	% change	ml/ min	gpm	% change
8002B-4	780	0.206		840	0.222	+7.69	870	0.230	+11.54	880	0.232	+12.82	890	0.235	+14.10	890	0.235	+14.10	890	0.235	+14.10
8002B-5	780	0.206		840	0.222	+7.69	870	0.230	+11.54	880	0.232	+12.82	890	0.235	+14.10	890	0.235	+14.10	890	0.235	+14.10
8002B-6	780	0.206		820	0.217	+5.13	850	0.225	+8.97	870	0.230	+11.54	880	0.232	+12.82	880	0.232	+12.82	880	0.232	+12.82
TOTAL	2340	0.618		2500	0.661	+20.51	2590	0.685	+32.05	2630	0.694	+37.18	2660	0.702	+41.02	2660	0.702	+41.02	2660	0.702	+41.02
Average	780	0.206		833	0.220	+6.84	863	0.228	+10.68	877	0.231	+12.39	887	0.234	+13.67	887	0.234	+13.67	887	0.234	+13.67
12NF-4	700	0.185		660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71
12NF-5	700	0.185		660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71
12NF-6	700	0.185		660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71
TOTAL	2100	0.555		1980	0.522	-17.13	1980	0.522	-17.13	1980	0.522	-17.13	1980	0.522	-17.13	1980	0.522	-17.13	1980	0.522	-17.13
Average	700	0.185		660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71	660	0.174	-5.71

TABLE X

WEAR TEST IX, NOZZLE DISCHARGE RATE AT 40 psi BEFORE AND AFTER USE AND
PERCENTAGE INCREASE IN DISCHARGE RATE AFTER USE.

SPRAY MIXTURE: NITRALIN, 2.66 POUNDS
+ 10 GALLONS WATER

Nozzle No.	Before use ml/min gpm		After use of														
			3.5 hours			7 hours			10.5 hours			14 hours			17.5 hours		
			ml/min	gpm	% in- crease	ml/min	gpm	% in- crease	ml/min	gpm	% in- crease	ml/min	gpm	% in- crease	ml/min	gpm	% in- crease
8004B-7	1550	0.410	1600	0.423	3.23	1620	0.428	4.52	1640	0.433	5.81	1640	0.433	5.81	1640	0.433	5.81
8004B-8	1490	0.394	1550	0.410	4.03	1580	0.417	6.04	1600	0.423	7.38	1600	0.423	7.38	1600	0.423	7.38
8004B-9	1540	0.407	1600	0.423	3.90	1620	0.428	5.20	1640	0.433	6.49	1640	0.433	6.49	1640	0.433	6.49
TOTAL	4580	1.211	4750	1.256	11.16	4820	1.273	15.76	4880	1.289	19.68	4880	1.289	19.68	4880	1.289	19.68
Average	1527	0.404	1583	0.419	3.72	1607	0.424	5.25	1627	0.430	6.56	1627	0.430	6.56	1627	0.430	6.56
8004HSS-1	1560	0.412	1560	0.412	0.00	1560	0.412	0.00	1560	0.412	0.00	1560	0.412	0.00	1560	0.412	0.00
8004HSS-2	1620	0.428	1620	0.428	0.00	1620	0.428	0.00	1620	0.428	0.00	1620	0.428	0.00	1620	0.428	0.00
8004HSS-3	1560	0.412	1560	0.412	0.00	1560	0.412	0.00	1560	0.412	0.00	1560	0.412	0.00	1560	0.412	0.00
TOTAL	4740	1.252	4740	1.252	0.00	4740	1.252	0.00	4740	1.252	0.00	4740	1.252	0.00	4740	1.252	0.00
Average	1580	0.417	1580	0.417	0.00	1580	0.417	0.00	1580	0.417	0.00	1580	0.417	0.00	1580	0.417	0.00

VITA

The author was born on February 22, 1942, in Vankaner, Surat, Gujarat, India. He received his B.S., with a major in Agriculture, from B. A. College of Agriculture, Sardar Patel University, Anand, Gujarat, India, in 1964. He worked in the Department of Agriculture, Gujarat State Government, India, for two years. In Fall, 1966, he came to The University of Tennessee, Knoxville, Tennessee, and worked for his M.S. in Agricultural Mechanization, in the Department of Agricultural Engineering,