March 8, 1968

To the Graduate Council:

I am submitting herewith a thesis written by Vernon Ellis Gordon entitled "Thermal Analysis of Non-hooded and Hooded Alfalfa Flamers." 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 Engineering.

Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:

Vice President for
Graduate Studies and Research

THERMAL ANALYSIS OF NON-HOODED AND HOODED ALFALFA FLAMERS

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

Vernon Ellis Gordon

June 1968

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TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
II.	OBJECTIVE	4
III.	REVIEW OF LITERATURE	5
IV.	MATERIALS AND METHODS	13
	Field Research	13
	Research sites	13
	Description of machines	13
	Field experiment number one	19
	Field experiment number two	21
	Laboratory Research	23
	Testing site	23
	Description of machines	23
	Testing equipment	25
	Procedure using hooded and non-hooded flamers	30
	Procedure for Manchester flamer	33
V.	DISCUSSION OF RESULTS	37
	Field Results	37
	Results of field number one	37
	Results of field number two	39
	Laboratory Results	41
	Results of hooded and non-hooded flamers	41
	Results of Manchester flamer	45

CHAPTER PAGE

VI. SUMMARY AND CONCLUSIONS 48

BIBLIOGRAPHY. 52

APPENDIX. 55

LIST OF TABLES

TABLE PAGE

I. Effectiveness of Winter Burning Using a Non-hooded Flamer for Control of Alfalfa Weevel Compared to Untreated Checks 38

II. Effectiveness of Winter Burning Using Hooded and Non-hooded Flamers for Control of Alfalfa Weevil 40

III. Temperature-Time Data Using Hooded and Non-hooded Flamers Obtained With an Oscillograph Instrument 44

IV. Temperature-Time Data Obtained with an Oscillograph Instrument for a Manchester Flamer 46

V. Temperature-Time Data for Alfalfa Flamer Without a Hood. . . 56

VI. Temperature-Time Data for Alfalfa Flamer With a Hood 61

VII. Temperature-Time Data for Manchester Alfalfa Flamer With Hood Down. 65

VIII. Temperature-Time Data for Manchester Alfalfa Flamer With Hood Up. 67

LIST OF FIGURES

FIGURE PAGE

1. View of the Hooded Flamer in Operation During the Field Research Tests 14
2. View of the Non-hooded Flamer Used in Both the Field and Laboratory Tests 16
3. Operator's View of the Gas Controls for the Hooded Flamer. . . 17
4. Operator's View of the Gas Controls for the Non-hooded Flamer. 18
5. Contrast Between the Dark Strip on Left Which was Burned with the Non-hooded Flamer and the Untreated Check on the Right. 20
6. Laboratory Testing Track for Alfalfa Flamers Located Near The University of Tennessee Agricultural Engineering Building 24
7. Front Isometric View of the Hooded Flamer After a Section of the Hood was Removed from the Front Row of Burners for the Laboratory Testing 26
8. Isometric Schematic of Thermocouple Arrangement for Laboratory Testing of Hooded and Non-hooded Alfalfa Flamers. . . . 27
9. Schematic Diagram of the Thermocouple Circuit Used to Obtain Temperature Data Under Dynamic Conditions 29
10. Front View of the Honeywell 1508 Visicorder Oscillograph in Operation Near the Laboratory Testing Track 31

FIGURE PAGE

11. Rear View of the Honeywell 1508 Visicorder Oscillograph Showing Thermocouple Wires and Connectors. 32

12. Sample Data Sheet of Temperature-Time Relationships Under an Alfalfa Flamer as Recorded on a 1508 Visicorder Oscillograph 34

13. View of the Manchester Flamer While Operating on the Laboratory Test Tract. (The Burners are Directly Above the Thermocouples Which are Connected to the Oscillograph on the Table.) 35

14. Effectively Burned Alfalfa Treatment Using the Hooded Flamer on March 22, 1967 on the Blount County Farm. 42

CHAPTER I

INTRODUCTION

The use of flame as a control for the alfalfa weevil, Hypera postica (Gyllenhal), has been known since 1910; however, it was not used extensively until the last few years. Previously, a chlorinated hydrocarbon insecticide, heptachlor, had been effectively used for weevil control. After restrictions were placed on heptachlor a tremendous increase in infestation of alfalfa fields by the alfalfa weevil occurred, and interest in flaming as a control was revived by researchers.

Dr. H. H. Tippins, University of Georgia, 1963, discovered the partial control of the weevil with flame when a fire accidentally broke out in some of his alfalfa plots. The research work in flame control for the weevil began at The University of Tennessee in 1964. Flaming alfalfa, followed with one spraying, is now the recommended practice for control of the weevil in Tennessee.

Knowledge of the life cycle of the weevil was necessary before it could be effectively controlled and sufficiently researched through flaming. The four stages of the weevil's life cycle are the egg, larva, pupa, and adult. The weevil is capable of wintering in both the egg and adult stages. However, the large number of eggs found in alfalfa stubble during the winter months indicate that the egg is the principal wintering stage (3).

The female deposits her eggs in the alfalfa stem in the fall and winter months, with some being laid in the new foliage during the early spring. The eggs number from one to forty, but usually average about a dozen in each deposit. The length of time required for the eggs to hatch depends primarily on the environmental temperatures (20). The eggs usually hatch from March until June in Tennessee.

The young larvae move from the stubble base to the tender growing bud of the alfalfa. They grow from less than 1/16 inch in length at birth and grayish white in color to 1/4 inch long and leaf-green when full-grown (17). After the larvae devour the leaf bud, they move to the open leaves, vigorously eating the selected soft tissue. Since the larva stage is the most destructive stage of the weevil, it is the one of primary importance. The larvae leave nothing except the woody fibers of the stem when they are left uncontrolled (20). The alfalfa fields take on a grayish appearance which resulted from the infestation of the larvae (17).

The larvae grow to maturity in about three to four weeks and move to the ground to spin loose, white cocoons, roughly spherical in shape, about the size of a small dried pea. The cocoons are usually found among the surface litter. After about ten days the adults emerge and feed on the alfalfa until high temperatures in the summer months cause them to seek shelter along the fence rows in the nearby woods (17).

The adult weevils notch main stems, sever side shoots and leaf stems, and feed upon the leaves. Their destructive behavior gives a

ragged appearance to the field. The appearance of the older weevils is distinctive because their thorax bears a dark double-barred pattern separated by a narrow light-colored line. A single dark circle can be seen on either side of the thorax. Older weevils are usually darker in color than the young ones (17).

The female adult weevils move back to the field to begin laying their eggs with the return of cool weather in the fall. The weevils burrow in the soil around the crown of the alfalfa plants during extreme cold weather (20).

The majority of alfalfa flamers on the market burn propane gas and are recommended as a control of the weevil. Therefore, having a machine to perform at optimum efficiency is required to receive effective burning of the alfalfa weevil. If the burners on the machine could be adjusted to produce more thermal energy beneath the burners than the amount they are presently producing, while consuming the same volume of fuel, then the cost per acre for using the alfalfa flamers could be reduced. The problem for this thesis was to test the flamer design with respect to the positioning or location of the burners for temperature variation.

CHAPTER II

OBJECTIVE

The primary objective in this investigation was to determine if hooded flamers were more effective than non-hooded flamers for control of the alfalfa weevil in the field. A secondary objective was to compare temperature variations beneath the flamers.

CHAPTER III

REVIEW OF LITERATURE

The thirty million acres of alfalfa harvested each year are worth over 1.5 billion dollars. The alfalfa weevils are capable of destroying this entire crop if they are left uncontrolled (11). It has been estimated that eight larvae per square foot can destroy a crop of alfalfa. However, as many as 200 larvae per square foot have been found on some farms in Tennessee (5).

Quinton (13) said that the alfalfa weevil was a native of Europe and Asia. It was first discovered in Utah in 1904, but remained west of the Rocky Mountains until 1952, when it was discovered in Maryland. Cavender (5) reported in the Spring of 1967 that the weevil was then found in 42 states. The only states that had not been invaded with the destructive pest were Alaska, Florida, Hawaii, Iowa, Maine, Minnesota, Oklahoma, and Texas. The weevil has been moving south and west at the rateoof 80 miles per year and moving north and northwest at the rate of 30 miles per year.

In 1959, Quinton recommended granular heptachlor as a pre-growth treatment which gave protection against the weevil until the first cutting (5). However, the heptachlor label for use on alfalfa was withdrawn in 1964 because of detectable residues. Many entomologists then recommended malathion and diazinon insecticides for weevil control. Malathion has been safer for use (11).

Laster and Davis (13) reported the insecticide, methyl parathion, applied at the rate of 0.5 pounds per acre, gave the greatest reduction in the number of larvae as compared to other insecticides. Two applications of this insecticide were needed to protect the alfalfa until the first cutting.

The total cost of chemical control, as reported by Cavender (5), varied from $5.70 to $13.42 per acre, depending on the kind of insecticide used and the number of applications. In contrast, the total cost of flame control plus one spray application ranged from $11.30 to $13.30 per acre.

C. C. Blickenstaff (11), USDA entomologist, said the sensitivity of the alfalfa weevil's body to heat has shown flaming to be a non-chemical approach to weevil control. Research showed that an exposure time of only one second and a temperature of 225°F. will kill the adult weevil. The larvae were killed at a lower temperature (8).

Winter flaming of dormant alfalfa should be considered only as a supplement to insecticides in the alfalfa weevil control program. No available insecticides have been effectively used at the time of the year when flaming is most beneficial.

A joint project was conducted at the University of Maryland in 1965 by Harris et al. (9) to obtain relationships between the intensity of heat in terms of temperature and duration and the degree of kill of the alfalfa weevil. The laboratory equipment that was developed consisted of a mobile heat source and a means of determining the changes

in temperature caused by the burning gases. He selected an oscillograph with lightbeam galvanometers to test the variation in temperature. The oscillograph was used to record the output from Chromel-Alumel thermocouples. The results indicated that an efficient control can be achieved with the use of heat. However, additional laboratory and field equipment must be developed and tested before the practice can be made feasible.

Steinhauer (19) conducted a more extensive field study in a combined research project with Harris et al. at the University of Maryland. His primary objective was to evaluate the field equipment that was being used to control the alfalfa weevil and its effect upon the different life stages of the weevil. The experimental flamer consisted of two rows of AFCO burners beneath a metal hood, 11' x 4', and mounted on a 3-point hitch. The front and rear rows of burners were mounted on 16" centers, while the rear row was off-center to the front row. The flamer used LP-gas and operated at 32 pounds per square inch, measured at the burner.

After the testing of this machine under field conditions, Steinhauer (19) concluded that it was possible, with improvements in the present equipment, for the practice of dormant flaming to become the best control of the alfalfa weevil. He also found the inadequate control of the weevil resulted when the established alfalfa was flamed after the crop had started to grow.

In the winter of 1962-63, Bennett and Luttrell (1) at The University of Tennessee became interested in the use of flame for controlling the alfalfa weevil in Tennessee. Straw was first used as a fuel to burn some alfalfa stubble in 1964. The resulting weevil and chickweed control encouraged further investigations. In 1964, a propane gas flamer was constructed on a rotary mower body. A series of tests were used to determine the forward speed and arrangement of burners which would be the most satisfactory for controlling the weevil. The results showed an outstanding control of chickweed and partial control of weevil populations. Only one insecticide application following the flaming was necessary for control until the first cutting.

It was reported by Pienkowski et al. (16) that weevil control by flaming was first tested in March, 1964, near Martinsville, Virginia. A Manchester flamer traveling at two miles per hour resulted in a low percentage of larvae killed. It was assumed that the larvae entered the green tips of the three inch high alfalfa and escaped the heat.

In 1965, the use of a Brunner flamer produced satisfactory control until harvest. The addition of a hover on the Manchester flamer did not significantly affect the weevil control. Results showed that flaming twice at higher speeds did not equal a single flaming at a slower speed (16).

A cooperative project among four departments at the University of Kentucky was begun in the winter of 1964. B. C. Pass et al. (14) studied the effect of some mechanical and cultural practices on the

alfalfa weevil. Using heptachlor as a standard, the results gave an indication that any of the cultural or mechanical practices would have to be accompanied with an application of insecticide to insure effective weevil control.

The principal objectives of the investigation which began in the spring of 1965 at The University of Colorado by Clark and Simpson (7) were to determine a flame treatment which would adequately control the alfalfa weevil and the effect of these treatments upon the yield per acre. After considering the problems encountered while collecting the data, Clark and Simpson concluded that flaming would minimize the hiding places of the weevil. Flaming also destroyed the eggs which had been deposited in the stubble and residue. Clark said a hovered flamer and some type of trash agitator could economically be used for this purpose. He also concluded that flaming the alfalfa stubble did not appear to decrease hay yields.

During 1966 research programs for the control of the alfalfa weevil continued at different universities and experiment stations. Various objectives were established and the research data was collected and analyzed.

Simpson and Clark (18) found in their 1966 investigation that all flame treatments reduced the yield significantly compared to the unflamed check plots. This result was probably due to a longer growth period for the check plots since the flamed plots had two to three inches of new growth at the time of flaming.

Chappel and Pienkowski (6) reported that Virginia had recommended winter burning of alfalfa by means of LP-gas flamers for the control of the alfalfa weevil. The results obtained from the 1966 investigations gave no consistent advantage to the use or non-use of a hover. Better results were obtained with a faster tractor speed and a higher pressure, as compared to a slower speed and lower pressure, while both burned the same amount of LP-gas per acre.

The results of the 1966 research in Kentucky indicated that flaming the alfalfa in its dormant stage, combined with one spray application of insecticide, gave effective control of the weevil until normal first harvest. This flaming technique also aided in controlling weeds, especially chickweed, when the flaming speed was below three miles per hour (15).

Blickenstaff et al. (2) reported in 1966 that design changes had been performed on their 1965 flamer. An additional 2-1/2 feet of metal hood was built onto the original flamer. Secondary air needed beneath the hood for maximum combustion was provided with two centrifugal blowers mounted on the flamer. Six branch air ducts, each of which were 4 x 8 inches, discharged the secondary air supply between the burners in the second row.

Because of the design changes on the flamer, the testing of temperature variation beneath the hood indicated that the 1966 machine traveling at two miles per hour was essentially equivalent to that of the 1965 machine traveling at 1-1/2 miles per hour. Blickenstaff

concluded that dormant flaming of alfalfa was very effective in reducing the adult weevil and egg population (2).

The performance of LP-gas burners was investigated by Buttiglier et al. (4). One of their objectives was to evaluate the burner systems while studying them under dynamic conditions in the laboratory. It was determined that the hood on the flamer would maximize the use of heat produced by the combustion reaction and would minimize the effects of change in ambient conditions.

The hood design was one foot square in cross section and had variable lengths up to nine feet. The burner was placed opposite the open end. The seven thermocouples chosen for testing had Chromel-Alumel elements and were placed perpendicular to the direction of travel of the burner. The distance of the burner above the thermocouples was determined through a series of tests to be most efficient when placed six inches apart (4).

The results of Buttinglier's data gave an energy term which was based on the area between the temperature-time curve and a base line of 200°F. This energy was a measure of the amount of heat applied at a point, such as the thermocouple. A plot of energy versus fuel pressure to the burner was given in the results (4).

An investigation, similar to the one conducted by Buttiglier et al. was conducted by S. A. Hassan et al. (10) at the University of Michigan. With their laboratory equipment and instruments, they proceeded to determine the speed of travel, inclination of burners, and the flaming arrangement most efficient for flame weed control (14).

The Chromel-Alumel thermocouples were again used as a means of measuring the temperature variation beneath the burners. The thermocouples' signals were recorded on three x-y recorders. The procedure required the burners to remain stationary while the thermocouples passed between them on a moving trolley. The vertical spacings of the three thermocouple junctions were two, five, and eight inches below the centerline of burner openings (10).

The thermocouples, while passing through the flame, sensed the local temperatures and transmitted a related signal back to the x-y recorders. The three x-y recorders plotted the signals as three continuous curves respective of the three thermocouples (10).

The results from the experiment showed in every case that higher peak temperatures were obtained at lower speeds at all three locations. Within the possibility of flaming arrangements, the highest temperatures resulted when the burners were inclined 30° to the horizontal. Hassan commented that an elaborate network of thermocouples would give better results, but would also require a multiple channel recording device, which was not available (10).

In 1967, Kentucky recommended using flame on dormant alfalfa in January, February, and March, before spring growth began. The non-hooded flamers were suggested because of the added expense and maintenance problems encountered with the hood models. The hovers did not improve the results as researched by Kentucky. The lack of sufficient oxygen beneath the hovers created additional problems with the hooded models (20).

CHAPTER IV

MATERIALS AND METHODS

I. FIELD RESEARCH

Research sites. The field research for this thesis was conducted at two different locations. The first field of alfalfa was the upper east section of the 30-acre field near Alcoa, Tennessee, across the highway from McGhee Tyson Airport. The block was approximately one acre in size.

The other field was six acres in size, located on The University of Tennessee Blount Farm in Blount County, Tennessee. Approximately one acre of the middle of this field was used as the research section.

Description of machines. Two different flamers, both of which burned propane gas, were used in the field research. The first machine, which was constructed on a 7-foot rotary mower body, was considered the hooded flamer (Figure 1). The shields on the sides and the front, combined with the hood, helped to retain the heat. The fuel tank was mounted about three feet above the body of the flamer. The fuel tank was protected from the intense heat by a 1/4-inch asbestos board which covered the top of the flamer. The asbestos board was also effective in reducing heat loss through the hood.

Two rows of A-130 AFCO burners were mounted on the flamer beneath the hood. One row consisted of six burners mounted 12 inches on



Figure 1. View of the hooded flamer in operation during the field research tests.

center and placed at the front of the machine. The second row was composed of seven burners mounted 12 inches on center and offsetting the front row a distance of six inches. The two rows of burners were separated by a distance of 30 inches. The outlets for all the burners were 12 inches above the ground and perpendicular to it.

A centrifugal blower powered by a Briggs and Stratton gasoline engine was mounted on the top of the hood in front of the fuel tank. This supplementary supply of air was required for more effective combustion of the gases beneath the hood. The secondary air was discharged at the rate of approximately 1000 cubic feet per minute through six air ducts, six inches by eight inches, between the two rows of burners.

It was known that maximum combustion of available fuels would result in optimum efficiency for the flamer; however, it proved to be very difficult to regulate the volume of secondary air discharged to the burners. Therefore, the secondary air was held constant for all treatments for both the field and laboratory research.

The other flamer used in the field research was constructed on a 3-point hitch (Figure 2). The fuel tank was directly behind the tractor operator and the burners were mounted behind the tank. There were two rows of AFCO burners, arranged identically the same as the hooded flamer previously described. The thirteen burners were mounted on a 2 x 2 x 1/4 inch angle-iron frame.

The gas controls for both flamers were mounted close behind the tractor operator (Figures 3 and 4). Therefore, the operator could

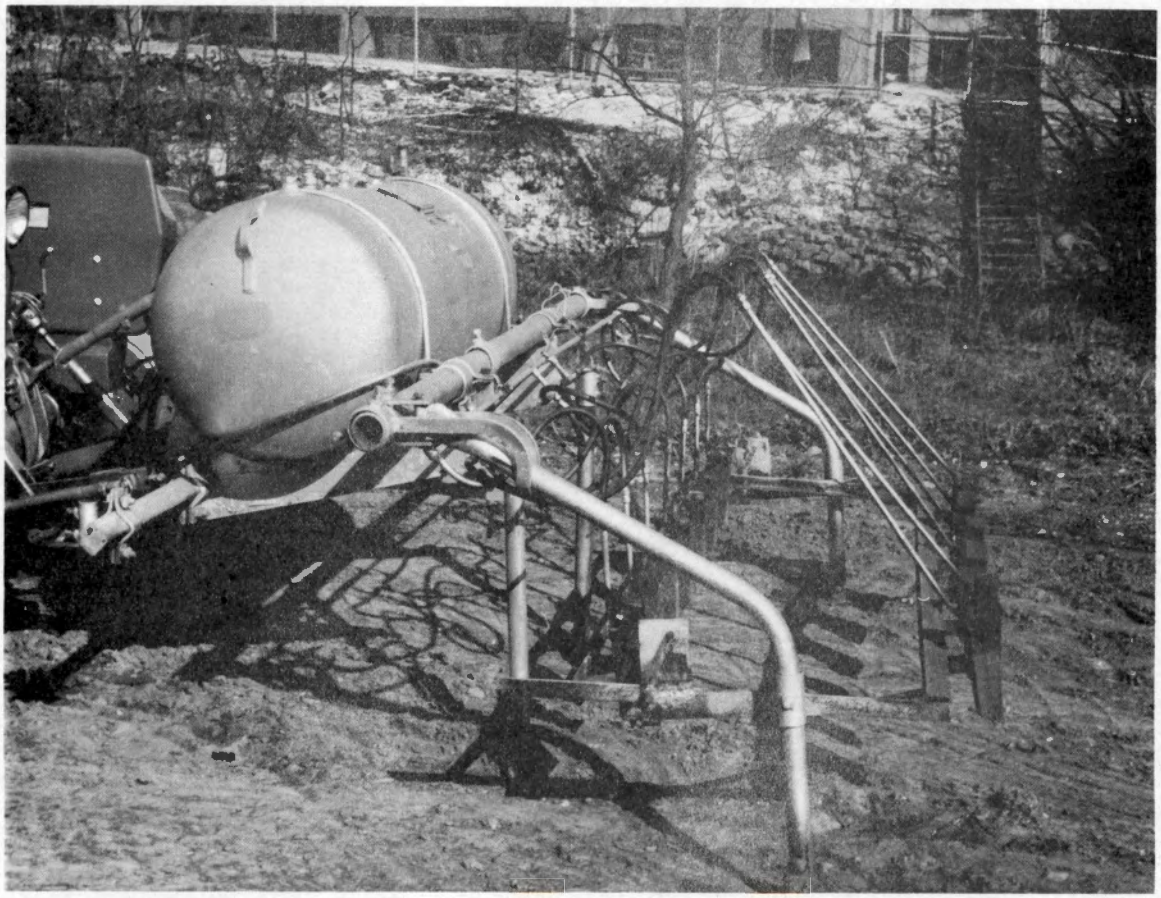


Figure 2. View of the non-hooded flamer used in both the field and laboratory tests.

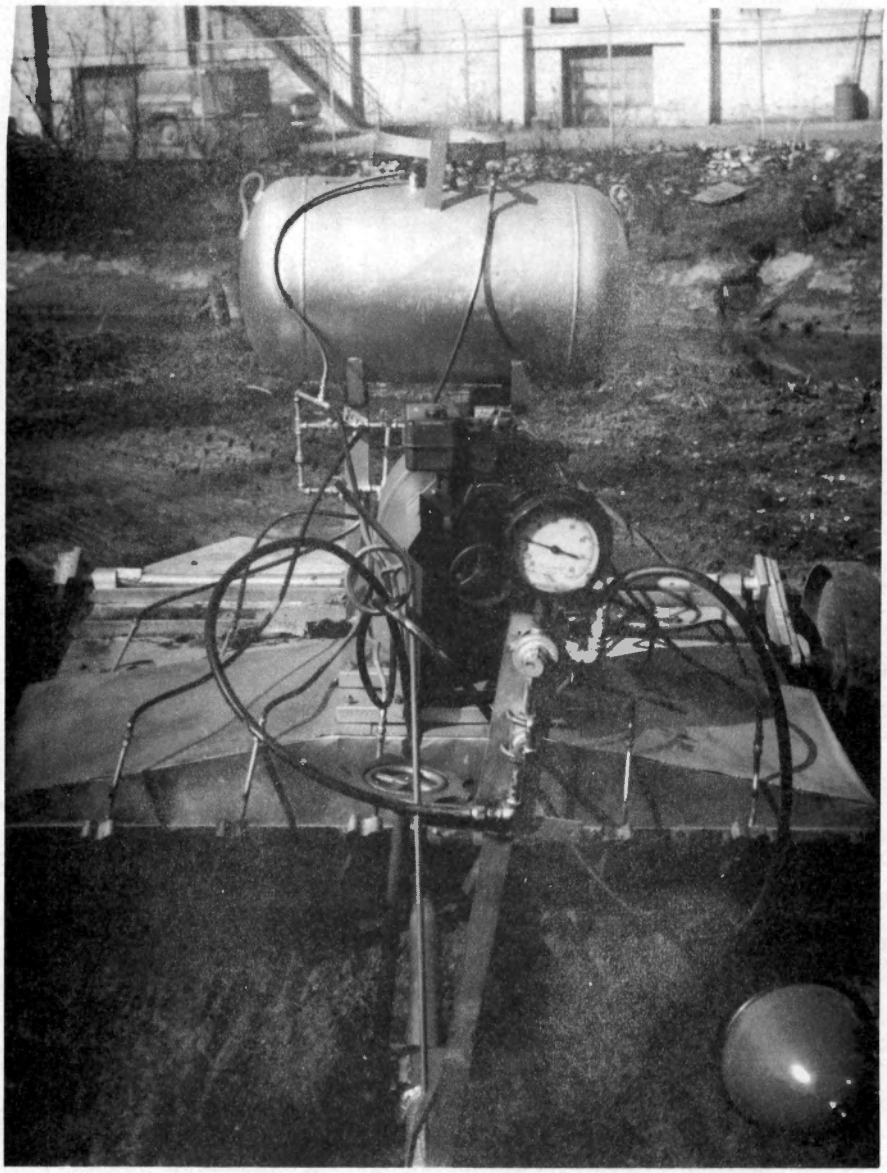


Figure 3. Operator's view of the gas controls for the hooded flamer.

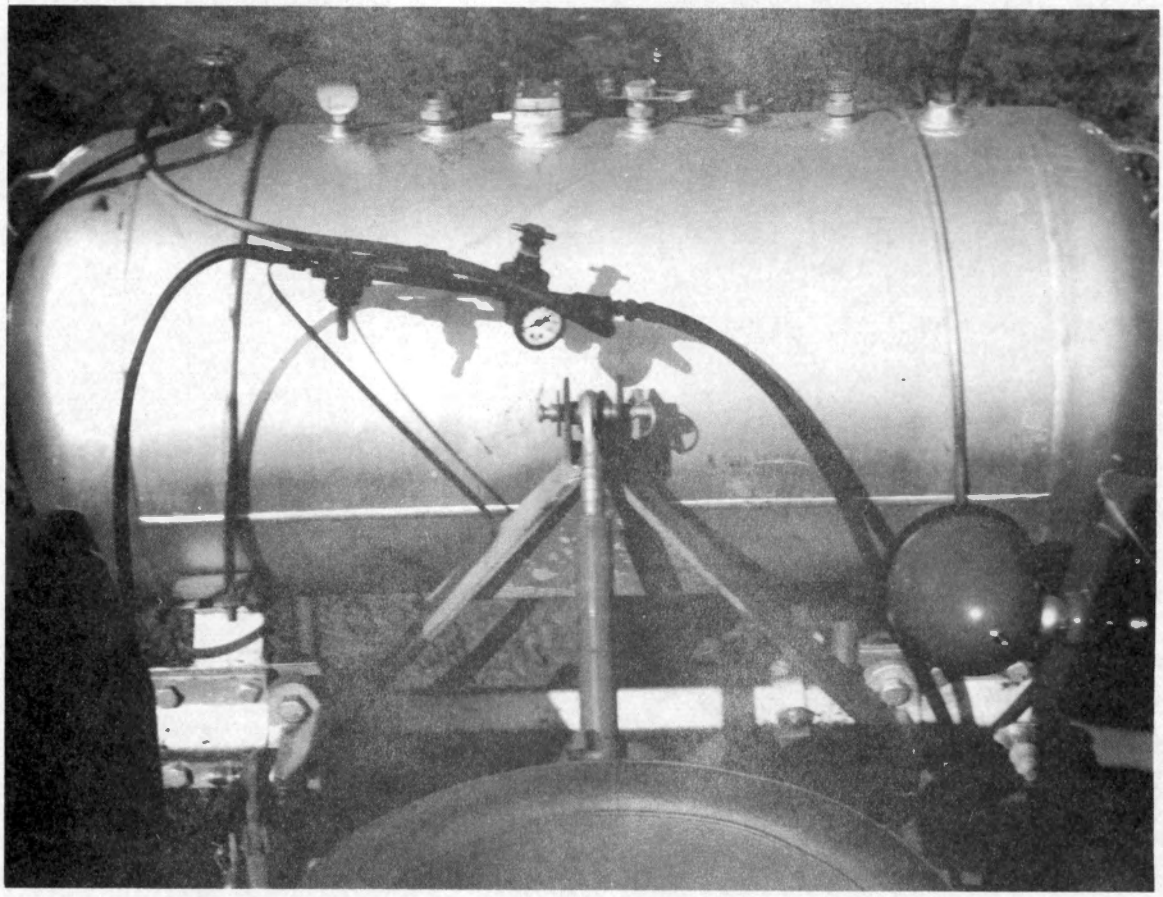


Figure 4. Operator's view of the gas controls for the non-hooded flamer.

regulate the flow of fuel to the burners without dismounting the tractor.

Field experiment number one. The first set of trials was performed on March 2, 1967, three days after an all-day rain on February 27. The temperature was in the upper fifties and the wind was about ten miles per hour, perpendicular to the direction of travel of the flamers.

The two flamers, one with a hood and one without a hood, were used in this trial. However, due to unsatisfactory performance of the hooded flamer, it will not be considered in the statistical analysis of the results.

Each plot was 7 feet by 50 feet with 15-foot alleyways between each replication. Figure 5 shows the contrast between one of the treatments burned with the non-hooded flamer and an untreated check. The specifications for this treatment were 45 pounds per square inch regulated pressure and two miles per hour tractor speed.

The treatments as well as the checks were sprayed with 16 ounces per acre technical malathion on April 6, 1967. The field conditions at the time of spraying were a temperature of 80°F. and a wind of fifteen miles per hour. The plots revealed that an earlier spraying, possibly three or four days earlier, would have been more beneficial toward weevil control.

The weevil counts for this trial were made on April 4 and April 14 from a sample collected from each treatment. A sample consisted of five sweeps with a 13-inch insect net. Visual foliar damage



Figure 5. Contrast between the dark strip on left which was burned with the non-hooded flamer and the untreated check on the right.

ratings were made at the same time as the weevil counts. The damage index was based on a scale of 0 to 10, in which 0 indicated no visual damage and 10 indicated very severe damage. These data and their significance will be given in the following chapter.

The second spray application for these treatments was applied on April 18. It was apparent that the first spraying had reduced the number of larvae considerably, and the second spraying controlled the weevils until the first cutting. Observation of the alfalfa after the second spraying showed new growth had begun from the bud and no visible holes had been eaten in the young tender leaves.

On April 21, yield samples were cut from strips, 3 feet by 25 feet in each plot. Then an approximate two pound random sample was weighed, dried, and reweighed for total dry matter. All yield data were based on pounds per acre dry matter.

Field experiment number two. The second set of trials was performed on March 22, 1967, on The University of Tennessee Blount Farm. The temperature was in the upper sixties and the wind was ten miles per hour, perpendicular to the direction of travel.

The same two flamers which were used in field number one were also used in this field research. Both machines operated satisfactorily during the plot flaming. The duration of the flame on any one point was varied by changing the forward speed of the tractor. The forward speeds were 2, 3, and 4 miles per hour, and the regulated pressures were 40, 50, and 60 pounds per square inch. These variables

were combined into eighteen treatments plus two untreated checks. A randomized block design with four replications was used.

The block design was improved relative to the design in field number one. The size of each treatment was increased to 8 feet by 50 feet and the alleyways were increased to a width of 25 feet. These improvements provided additional space needed for more efficient maneuvering of the flamers.

On April 7, the research section of the field was sprayed with technical malathion. However, later appearance of the field indicated that the first spraying was not effective in destroying the larvae due to a malfunction with the spraying apparatus.

The field was sprayed the second time on April 19. This application of 16 ounces per acre of technical malathion was very effective in killing the larvae and adult weevils. The weevil count and foliar damage rating had been made on April 14, which was between the two spray applications. The late flaming of this field set the alfalfa growth back approximately ten days in relation to the remaining section of the field which had been flamed during the dormant stage of the alfalfa in the latter part of January.

On May 9, yield samples were cut from strips, 3 feet by 25 feet, in each plot for replications one and two. The total weight was recorded and then an approximate two-pound random sample was weighed, dried, and reweighed for total dry matter. The samples were harvested from replications three and four on May 18. The difference in harvesting

dates was due to harvesting problems encountered after the first two replications had been cut.

The significance of the weevil count, foliar damage rating, and the yield data may be found in the following chapter. These field results were compared to the laboratory study which was conducted as explained below.

II. LABORATORY RESEARCH

Testing site. The laboratory research was performed on an oval track (Figure 6) near The University of Tennessee Agricultural Engineering Building. The track was 10 feet in width and had a 75-foot straight stretch which was used as an approach section to the testing equipment by the tractor and flamer. The approach section was level in order for the height of burners to have uniformity relative to the ground. Electrical power was supplied to the track area.

The laboratory testing of the two flamers was done under environmental conditions which were very similar to actual field conditions. The wind velocity was five miles per hour or less and the temperature was 45°F.

Description of machines. The non-hooded flamer was the same machine that was used in the field research, as described earlier in this chapter. However, there were two changes made on the hooded flamer. The results of the field research had indicated that the volume of secondary air discharged under the hood was very critical.



Figure 6. Laboratory testing track for alfalfa flamers located near The University of Tennessee Agricultural Engineering Building.

Therefore, a section of the hood and the front shield were removed from the front row of burners in order to have a more uniform air supply (Figure 7). The blower was operated at the same speed as in the field research. Then the six burners on the front row were tilted backward from a vertical position to a position of 30° from the vertical. This position of the burners directed the flame backward under the hood. These two adjustments on the hooded flamer produced more efficient combustion of the gases beneath the hood. The rubber tires were replaced by steel wheels on the hooded flamer.

Testing equipment. In order to adequately examine the changes in temperature beneath the burners, a direct measurement of the temperature-time history had to be made. The selection of Chromel-Alumel thermocouples for this type of testing was considered to be the solution. This type of thermocouples is capable of measuring the rapid changes in temperature caused by the combustion of the gases beneath the hood.

A total of ten thermocouples was placed in a rigid frame, shown in Figure 8, to offset any error due to inaccurate positioning of them underground. They were spaced six inches apart in the frame. The thermocouples mounted in the wooden frame were buried on the track perpendicular to the direction of travel of the flamers and extended one inch above the ground surface. The flamers were driven over the thermocouples in such a manner that a thermocouple was directly below the burners over a total width measurement of 60 inches.

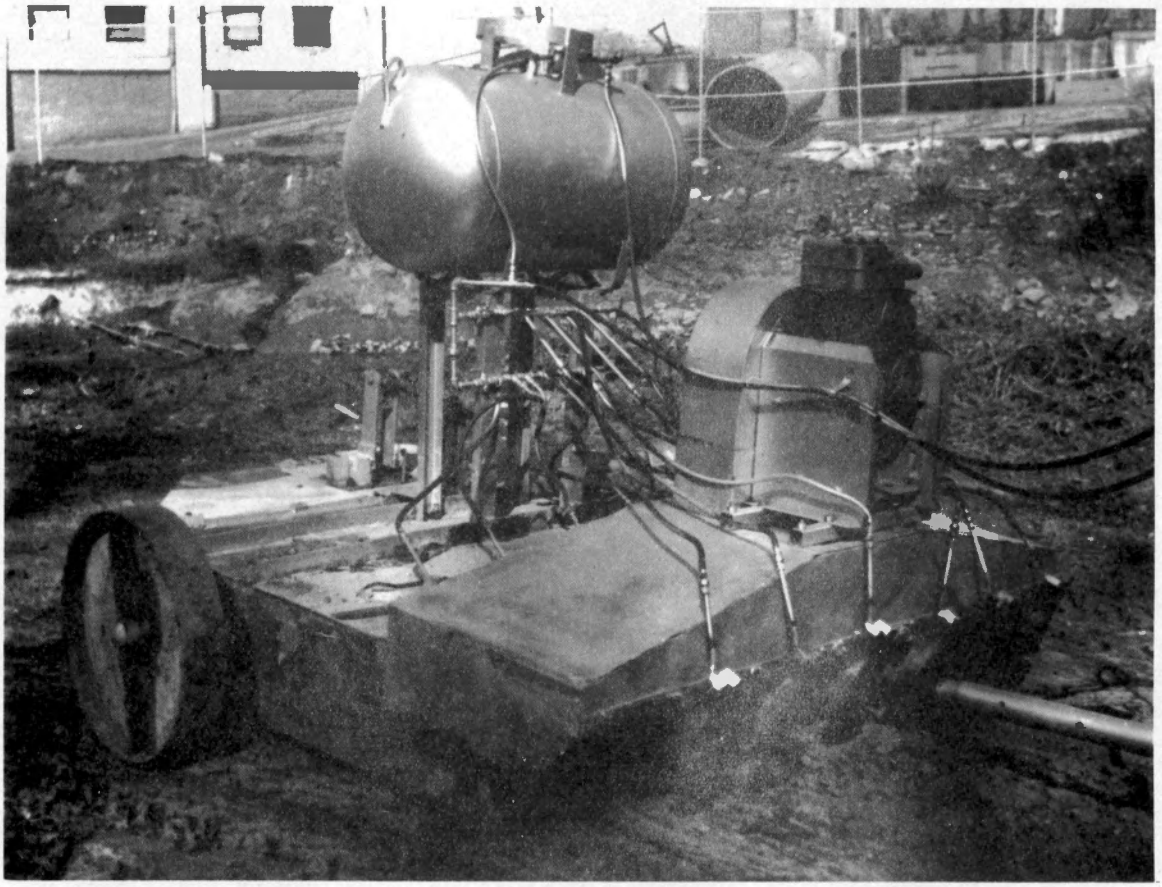
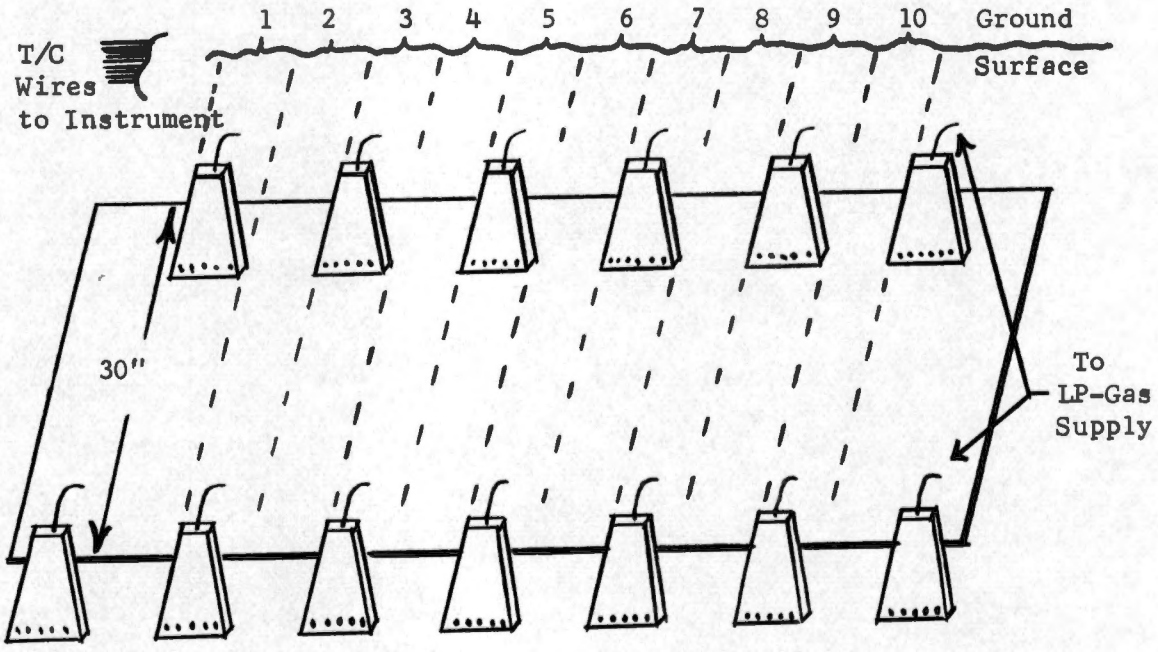


Figure 7. Front isometric view of the hooded flamer after a section of the hood was removed from the front row of burners for the laboratory testing.



Notes: (1) Ten thermocouples are spaced on 6-inch centers and one inch above the ground surface.

(2) AFCO burners are spaced on 12-inch centers and operate 12 inches above ground surface.

(3) Broken lines indicate flame pattern over the thermocouples.

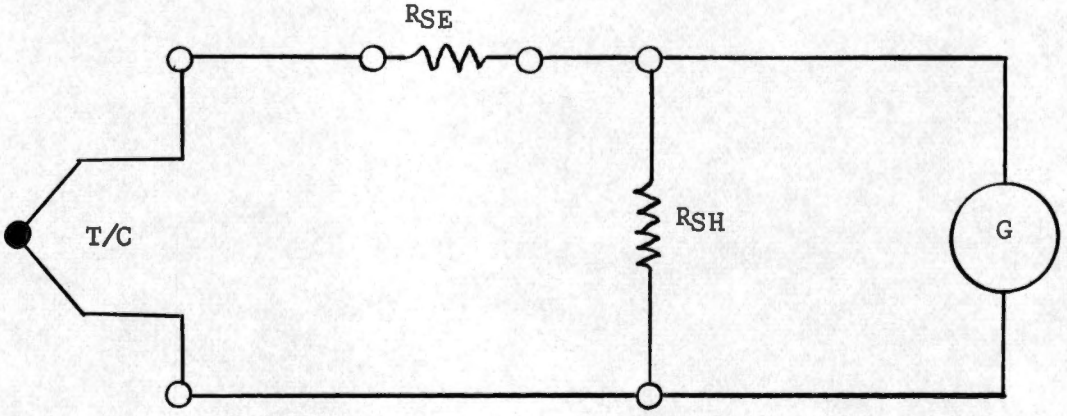
(4) Numbers indicate arrangement of thermocouples.

Figure 8. Isometric schematic of thermocouple arrangement for laboratory testing of hooded and non-hooded alfalfa flamers.

A multi-point recording instrument was required to record the output of the thermocouples as the flamer passed over them. Due to the very fast response that was required by the recording instrument, it was necessary to purchase an oscillograph for this research project. A Honeywell 1508 Visicorder Oscillograph instrument containing "Series M" subminiature lightbeam galvanometers was used to record the change in temperature of the thermocouples relative to time. The M200-120 galvanometers had a frequency response of 200 cycles per second which was fast enough to accurately record the output signals from the thermocouples.

The sensitivity of the deflection for the lightbeam galvanometers was varied by changing the series and shunt resistors in the circuit shown in Figure 9. The first trial was to establish an approximate three-inch deflection for 2000°F. temperatures. This was accomplished by using 402 ohm series resistors and 170 ohm shunt resistors in the resistor boards of the oscillograph. These resistors with a $\pm$ 1 per cent tolerance also gave an impedance matching between the thermocouples and the galvanometers.

After preliminary tests with the flamers, it was obvious that the sensitivity of the galvanometers needed to be changed. This change was a result of inadequate deflection readings when the flamer was driven over the thermocouples. By using 200 ohm series resistors and 316 ohm shunt resistors in the resistor boards, all of which had $\pm$ 1 per cent tolerance, the sensitivity of the galvanometers produced a 3-inch deflection for 1000°F. temperatures.



G = Galvanometer

R_{SE} = Series Resistor

R_{SH} = Shunt Resistor

T/C = Thermocouple Measuring Junction

Figure 9. Schematic diagram of the thermocouple circuit used to obtain temperature data under dynamic conditions.

The oscillograph instrument was calibrated by using a potentiometer to measure the millivolt input relative to the deflection on the oscillograph. These data were used to plot a graph of millivolt output versus deflection. Then a set of conversion tables was used to obtain a relationship between millivolts and degrees Fahrenheit temperatures for the Chromel-Alumel thermocouples. The curve which resulted from the previous conversion had a linear relationship between the temperature and the deflection. The slope of the linear curve gave an increase of 330°F. per one inch increase in deflection.

In order to check the system under known conditions, the outputs of the thermocouples were determined by using a material known as Tempilag which was known to melt at 344°F. The results of these tests were in agreement with the predicted melting point of the material.

Procedure using hooded and non-hooded flamers. The oscillograph instrument was carried to the test track in a well-constructed plywood box which reduced the danger of damaging the instrument. The instrument was placed on a table and connected to the power supply. Then the thermocouple leads were connected to the instrument (Figures 10 and 11).

On January 18, 1968, the non-hooded flamer was tested for the temperature history beneath each of ten consecutive burners. The tractor and flamer passed over the thermocouples, which were eleven inches below the mouth of the burners. The instrument was turned on as the tractor approached and turned off a short time after the flamer had

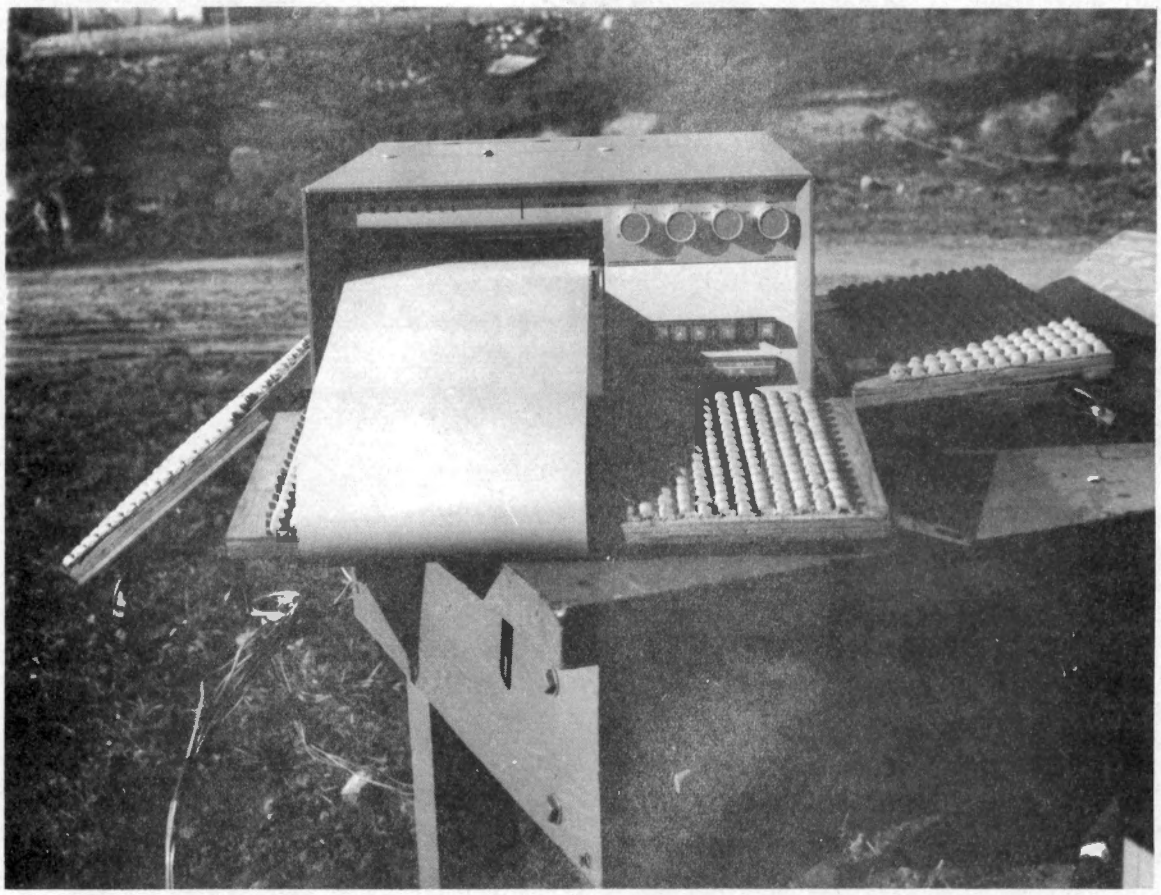


Figure 10. Front view of the Honeywell 1508 Visicorder Oscillograph in operation near the laboratory testing track.

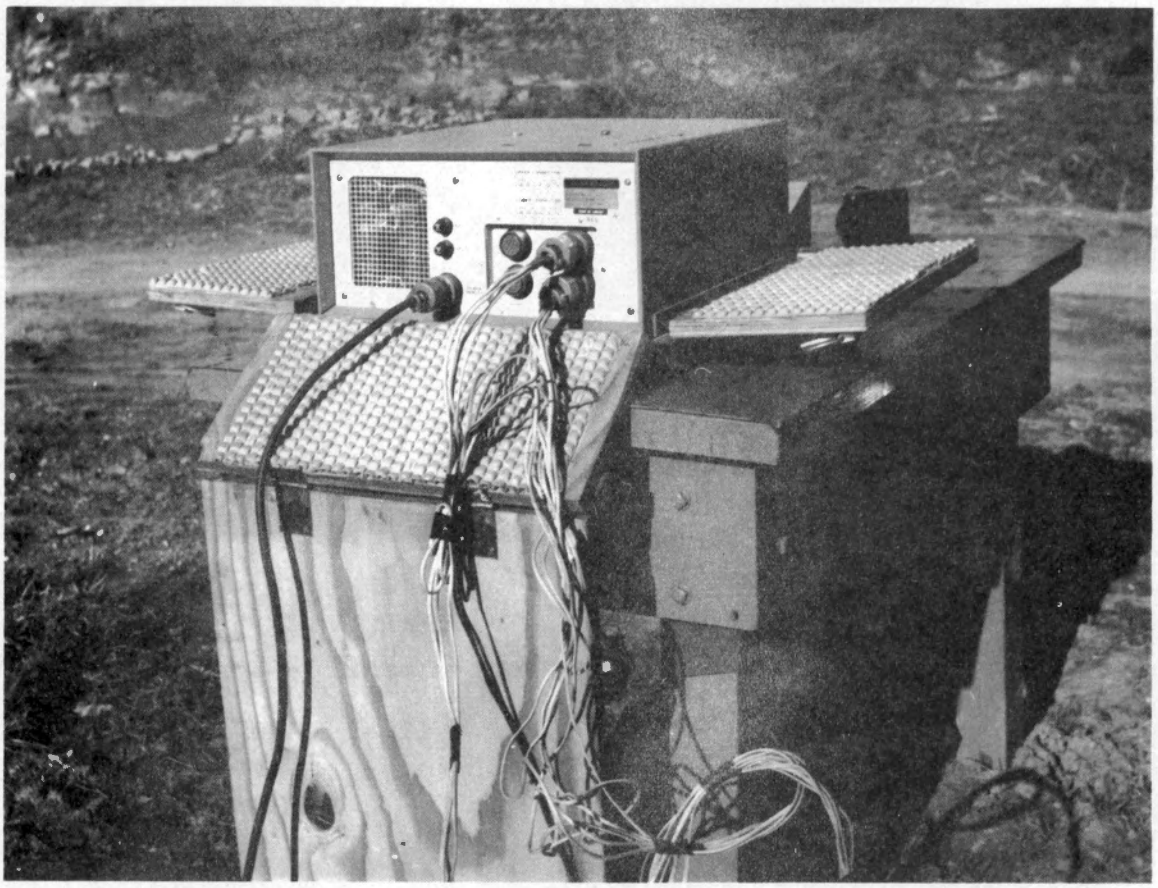


Figure 11. Rear view of the Honeywell 1508 Visicorder Oscillograph showing thermocouple wires and connectors.

passed over the thermocouples. The recording duration was approximately 20 seconds for each of the twelve treatments replicated four times. The outputs of each of the ten thermocouples were recorded simultaneously on the photographic paper (Figure 12). The thermocouple numbers on this figure correspond to the same numbers presented in Figure 8, page 27, and Tables V to VIII in the Appendix.

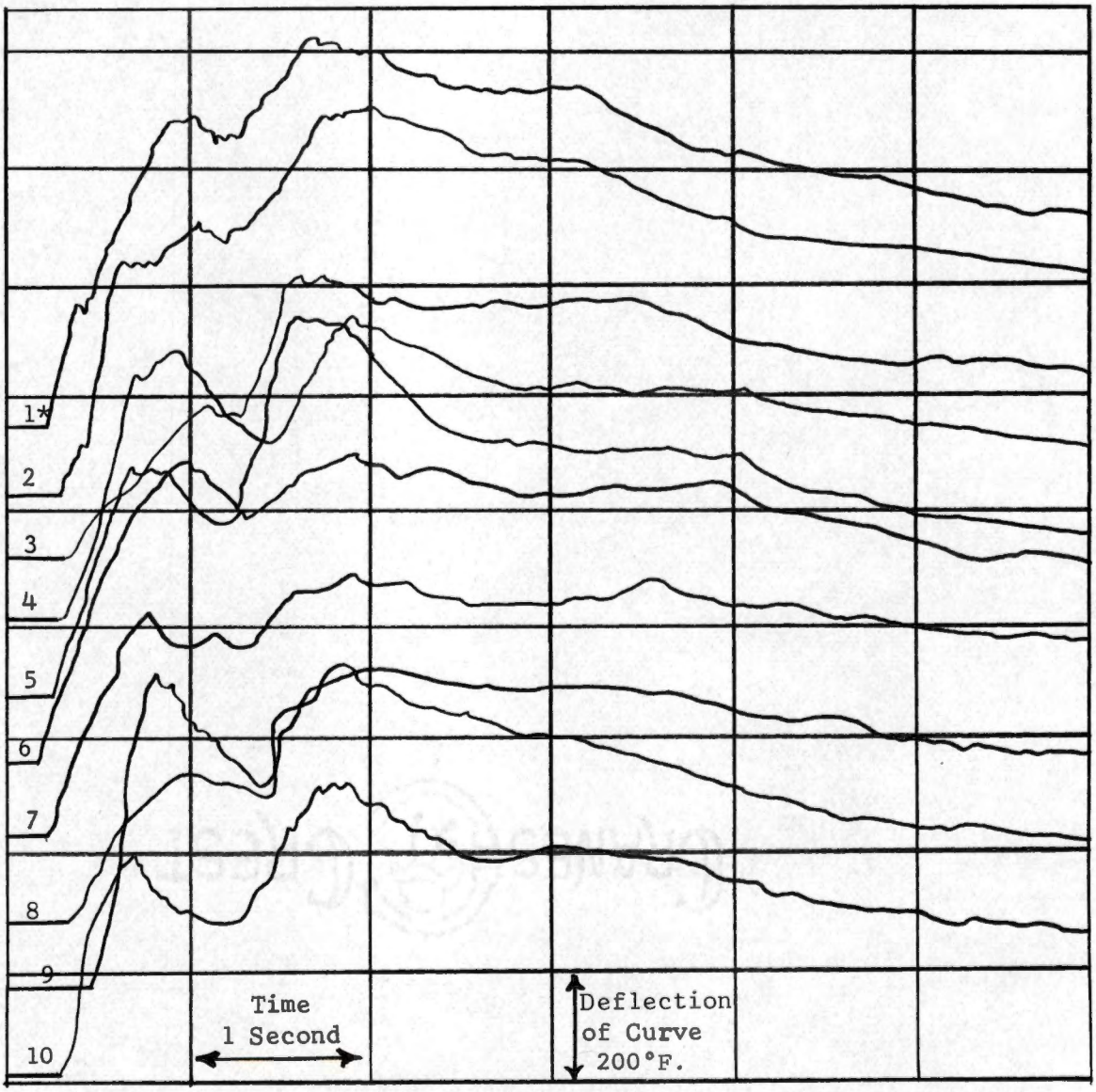
In order for the tractor to travel in the same tracks during each test run, wooden stakes were placed on each side of the thermocouples to be used as guides for the operator. The same tractor operator was used for all of the laboratory testing.

The tractor speed was calibrated by measuring the period of time required to travel 100 feet. The other variable in the treatments was the gas pressure, which was recorded as the regulated pressure.

The thermal testing of the hooded flamer was performed on February 6, 1968. The same procedure was used for both flamers.

Procedure for Manchester flamer. An additional experiment was included in the laboratory research which had not been used in the field research. A Manchester, Power Flame 12, heavy duty field flamer was tested on January 27, 1968. Using this flamer, it was possible to test for the temperature history of the burners while the hover was up or while the hover was down (Figure 13).

Because of the cold ambient temperature on the day that the machine was tested, a regulated pressure of only 80 pounds per square inch was obtained. Thus, while the pressure was held at 80 pounds per



*Numbers correspond to the thermocouple position.

Figure 12. Sample data sheet of temperature-time relationships under an alfalfa flamer as recorded on a 1508 Visicorder oscillograph.

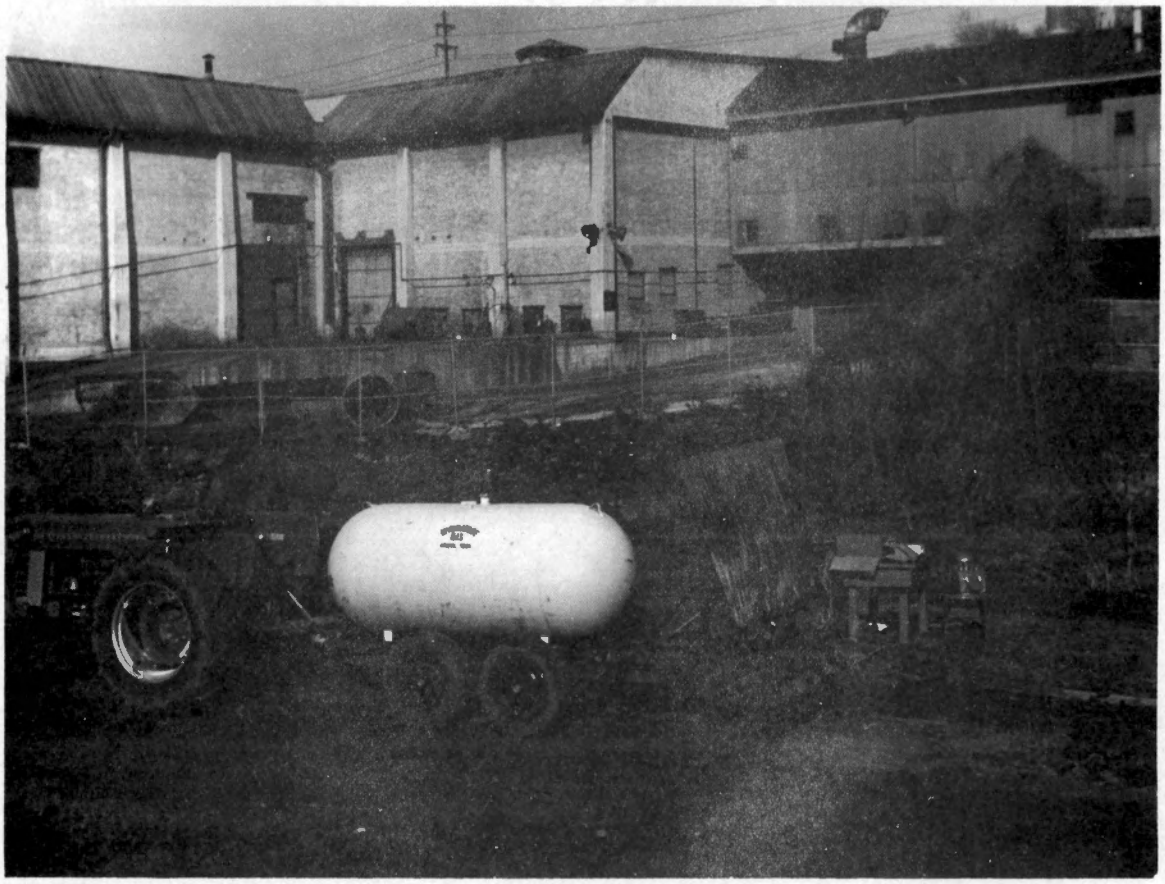


Figure 13. View of the Manchester flamer while operating on the laboratory test track. (The burners are directly above the thermocouples which are connected to the oscillograph on the table.)

square inch, the speed was varied from one to four miles per hour. A total of eight treatments, four with the hover down and four with the hover up, was replicated four times.

The 12-foot flamer had twelve FJ-12 burners mounted in two sections. Each section contained six burners spaced on 12-inch centers. Only one of these sections was used in the laboratory testing. Since the burners were spaced 12 inches apart and the thermocouples were only 6 inches apart, this meant that alternate thermocouples recorded the temperature directly below each of the middle four burners. The other five thermocouples recorded the temperature at the mid-point between the burners. An over-all width measurement of 54 inches was possible by using nine thermocouples.

CHAPTER V

DISCUSSION OF RESULTS

I. FIELD RESULTS

Results of field number one. The treatments on the Alcoa farm were burned with a non-hooded flamer on March 2 and were sprayed twice with malathion before first cutting. The yield data collected on April 21 reflected a low yield per acre compared to the high cost of producing the first cutting. The primary reason for this low yield was attributed to the dry weather encountered during the regrowth period for the alfalfa after the flaming.

Only one spray application would have been necessary for control of the weevil if it had been administered properly and at the proper time. The two spray applications insured weevil control until the first cutting.

A statistical analysis of the yield data (Table I) indicated no significant difference between the treatment, 25 pounds per square inch pressure, two miles per hour speed on the non-hooded flamer; as compared to the treatment, 45 pounds per square inch, two miles per hour speed, on the same flamer. This indicated a more economical flaming program if the flamer were operated at 25 pounds per square inch pressure instead of 45 pounds per square inch.

The statistical analyses for the foliar damage rating and the larvae count are also presented in Table I. The results of the larvae

TABLE I

EFFECTIVENESS OF WINTER BURNING USING A NON-HOODED FLAMER FOR CONTROL OF ALFALFA WEEVIL COMPARED TO UNTREATED CHECKS[a]

Treatment	Dry Matter Yield Pounds Per Acre[b]	Foliar Damage Rating[c]	Number of Larvae Per 5 Sweeps
45-2-NH[d]	1201 a[e]	1.33 a	85.0 abc
45-3-NH	954 ab	2.00 a	88.3 abc
35-3-NH	927 ab	4.66 cde	85.7 abc
35-2-NH	916 ab	2.66 abc	80.7 abc
25-2-NH	869 abc	3.66 bcd	106.0 bc
45-4-NH	649 bcd	3.66 bcde	105.7 bc
25-3-NH	631 bcd	6.33 e	86.7 abc
25-4-NH	595 bcd	6.33 e	107.0 bc
35-4-NH	562 bcd	5.66 de	133.3 c
Check	430 cd	10.00 f	37.7 a
Check	317 d	10.00 f	65.0 ab

[a] Flamed on March 2, 1967, one-acre section of 30-acre field owned by Alcoa Aluminum Company, located near Alcoa, Tennessee.

[b] Harvested on April 21, Average of three replications were used for yield data, damage rating, and larvae count.

[c] Rating based on scale of 0 to 10 where 0 = no visual change and 10 = very severe damage with 1 through 9 being intermediate. Damage rating and larvae count were made on April 4.

[d] Pounds per square inch regulated pressure--miles per hour forward ground speed--no hood (NH) flamer.

[e] 5 percent level of significance according to Duncan's multiple range test.

count implied there was no significant difference between the untreated check and the highest yield treatment, 45 pounds per square inch pressure and two miles per hour speed for the non-hooded flamer. This could be attributed to the observation that the larvae had completely destroyed the alfalfa on the untreated checks and had migrated to the adjacent flamed plots. This migration of the larvae resulted in a higher larvae count per sweep for the high yield treatments than for the untreated checks. It was also possible that the larvae in the untreated checks were close to the ground and did not get caught in the 13-inch insect net.

Results of field number two. The second set of field trials which were conducted on the Blount County farm indicated good weevil control. A statistical analysis for the yield data is presented in Table II. There was no significant difference among the first eight high-yield treatments which were performed by both the hooded and non-hooded flamers. The results also indicated that the treatment, 40 pounds per square inch pressure and two miles per hour speed for the non-hooded flamer, was as effective as the treatment, 60 pounds per square inch pressure and two miles per hour speed for the hooded flamer.

Observations of the yield samples collected from the untreated checks and some of the less effectively flamed treatments revealed the amount of alfalfa present in the samples was very little or none. Most of the yield weight had resulted from chickweed, onions, and wild weeds. On the other hand, most of the more effectively flamed treatments had

TABLE II

EFFECTIVENESS OF WINTER BURNING USING HOODED AND NON-HOODED FLAMERS FOR CONTROL OF ALFALFA WEEVIL[a]

Treatment	Dry Matter Yield Pounds Per Acre[b]	Foliar Damage Rating[c]	Number of Larvae Per 5 Sweeps
40-2-NH[d]	1725 a[e]	2.8 ab	33.8 f
60-2-H	1581 ab	2.8 ab	75.0 a
60-2-NH	1441 abc	1.3 a	22.0 hi
60-3-NH	1417 abc	4.5 bcd	41.5 e
50-2-NH	1304 abcd	4.0 abc	66.0 b
60-3-H	1243 abcd	7.0 cdef	52.8 d
50-3-H	1233 abcd	6.0 cde	24.8 gh
50-3-NH	1230 abcd	6.8 cdef	62.0 c
40-4-H	1144 bcde	7.5 def	32.0 f
50-4-NH	1128 bcde	7.0 cdef	26.3 g
50-2-H	1076 bcdef	6.8 cdef	21.5 i
40-2-H	925 cdef	7.5 def	44.0 e
Check	910 cdef	10.0 f	0.3 k
40-4-NH	859 def	9.5 f	3.0 k
60-4-NH	801 def	9.0 ef	7.0 j
60-4-H	786 def	9.5 f	22.8 hi
Check	686 ef	10.0 f	0 k
40-3-NH	636 ef	9.0 ef	32.3 f
40-3-H	559 f	10.0 f	2.7 k
50-4-H	557 f	9.5 f	24.5 ghi

[a] Flamed on March 22, 1967, The University of Tennessee Blount Farm, Knoxville, Tennessee.

[b] Harvested on May 9 and May 18. Average of four replications was used for yield data, damage rating, and larvae count.

[c] Rating based on scale of 0 to 10 where 0 = no visual damage and 10 = very severe damage with 1 through 9 being intermediate. Damage rating and larvae counts were made on April 14.

[d] Pounds per square inch regulated pressure--miles per hour forward ground speed--no hood (NH) or hood (H) flamers.

[e] 5 per cent level of significance according to Duncan's multiple range test.

very clean alfalfa which was a height of 12 to 15 inches. Figure 14 shows an effectively flamed treatment in the center compared to the less effectively flamed treatments on either side of it.

The statistical analyses of the foliar damage rating and the larvae count are also presented in Table II. The foliar damage ratings were in agreement with the dry matter yield harvested from the treatments. However, the high larvae counts represent very poorly the more effectively flamed treatments. This situation was caused by the fact that more larvae were eating on the alfalfa in these treatments when the larvae count was taken. The untreated checks and the less effectively flamed treatments had no visual alfalfa for the larvae to eat. Therefore, the larvae were assumed to be close to the ground and did not get swept up in the 13-inch insect net. It was also visible that many larvae had migrated a few inches into adjacent plots which had more alfalfa growth.

Since the first of two spray applications on this alfalfa field was considered ineffective, the results indicated that one spray application controlled the weevil until the first cutting. This was caused partly by the late flaming of this field. The early spring and the type of weather encountered were other reasons for only one spray application being necessary.

II. LABORATORY RESULTS

Results of hooded and non-hooded flamers. Using the data produced by the oscillograph, the area between the temperature-time curves



Figure 14. Effectively burned alfalfa treatment using the hooded flamer on March 22, 1967 on the Blount County farm.

and a base of 200°F. was determined with a planimeter. This area under the curve for each of 24 treatments gave the thermal energy available at a point measurement. The average values of three replications for the area under the temperature-time curves for ten thermocouples are presented in Table III for the hooded and non-hooded flamers.

The results of the treatments, indicated a significant difference between treatments of one mile per hour and the other speeds. Thus, the changing of the speed appeared more influential on the area recorded under the temperature-time curve than the changing of the pressure.

With reference to the objectives of this research project, the laboratory results indicated the hooded flamer to be more effective in producing the thermal energy required to kill the larvae and adult weevils. However, as the speed was increased from two to three miles per hour, the results implied no significant difference between the hooded and non-hooded flamers for the same pressures. The thermal energy available at a point became considerably less as the speed was increased to four miles per hour.

Both the field and laboratory results indicated that the hooded and non-hooded flamers had less effective burning capacity when the forward speed was increased. The laboratory results specifically indicated that more than twice as much thermal energy was available to kill the larvae when traveling at one mile per hour as compared to a speed of two miles per hour. This statement proved true for both flamers traveling two miles per hour compared to four miles per hour. Thus, two

TABLE III

TEMPERATURE-TIME DATA USING HOODED AND NON-HOODED FLAMERS OBTAINED WITH AN OSCILLOGRAPH INSTRUMENT[a]

Treatment	Area Under the Curve ($in.^2$)[b] Replications I	II	III	Mean	
60-1-H[c]	14.44	14.98	10.72	13.38	a[d]
60-1-NH	8.53	8.58	9.15	8.75	b
40-1-H	10.06	7.19	6.90	8.05	bc
50-1-NH	7.18	8.07	6.67	7.31	c
50-1-H	6.64	7.10	7.84	7.19	c
40-1-NH	5.85	6.31	5.18	5.78	d
60-2-H	4.57	5.20	5.50	5.09	d
60-2-NH	3.05	3.43	2.67	3.05	e
50-2-H	3.30	3.04	1.96	2.77	ef
60-3-H	2.42	2.76	2.83	2.67	efg
40-2-H	2.66	2.36	2.41	2.48	efg
50-2-NH	2.04	1.83	2.20	2.02	efgh
40-2-NH	1.52	1.88	1.62	1.67	fghi
50-3-H	1.10	1.44	1.83	1.46	ghij
60-4-H	0.93	0.74	1.13	0.93	hij
60-3-NH	0.90	0.83	0.81	0.85	hij
40-3-H	0.55	1.12	0.72	0.80	hij
50-4-H	0.74	0.93	0.57	0.75	hij
40-3-NH	0.45	0.73	0.40	0.53	ij
50-3-NH	0.30	0.45	0.71	0.49	ij
60-4-NH	0.44	0.40	0.37	0.40	j
40-4-H	0.23	0.28	0.33	0.28	j
50-4-NH	0.30	0.26	0.26	0.27	j
40-4-NH	0.19	0.22	0.21	0.21	j

[a] Data for the non-hooded and hooded flamers were collected January 18 and February 6, respectively. Testing track was located near The University of Tennessee Agricultural Engineering Building.

[b] A base of 200° F. was used.

[c] Pounds per square inch regulated pressure--miles per hour forward ground speed--no hood (NH) and hood (H) flamers.

[d] 5 per cent level of significance according to Duncan's multiple range test.

trips over a field with a flamer, hooded or non-hooded, at four miles per hour did not give nearly as effective a control as one trip over the field at two miles per hour.

A more detailed summary of the data collected from the hooded and non-hooded flamers is presented in Tables V and VI in the Appendix. The peak temperature recorded for any thermocouple was 996°F., as shown in Table V in the Appendix. This temperature was recorded for the treatment 50 pounds per square inch pressure and one mile per hour for non-hooded flamer. The non-hooded flamer obtained higher peak temperatures initially, but it could not retain the heat over a period of time as compared to the hooded flamer.

Results of Manchester flamer. As discussed in the procedure for this flamer, a constant regulated pressure reading of 80 pounds per square inch was used with the variable speeds. The results of the temperature-time curves for this set of treatments are presented in Table IV.

The results of the treatments performed with the hood indicated a favorable difference when compared to the same treatment without the hood. In fact, all of the treatments with the hooded flamer resulted in higher values for the area under the curve when compared to the treatments with the non-hooded flamer. This indicated a favorable response to operate this machine with the hood in order to obtain a more effective weevil control while maintaining the same cost per acre.

TABLE IV

TEMPERATURE-TIME DATA OBTAINED WITH AN OSCILLOGRAPH INSTRUMENT FOR A MANCHESTER FLAMER[a]

Treatment	Area Under Temperature-Time Curve ($in.^2$)[b]				
	Replications				
	I	II	III	IV	Mean
80-1-NH[c]	13.59	11.51	10.49	10.42	11.50
80-2-NH	3.16	5.81	3.34	5.88	4.39
80-3-NH	2.23	1.28	2.50	1.58	1.90
80-4-NH	1.47	1.08	1.03	0.77	1.09
80-1-H	13.83	14.28	13.92	14.69	14.18
80-2-H	5.04	5.88	5.09	5.01	5.26
80-3-H	2.43	2.72	2.31	2.93	2.60
80-4-H	1.42	1.30	1.27	1.21	1.30

[a]Data for Manchester flamer were collected January 27, 1968. Testing track was located near The University of Tennessee Agricultural Engineering Building.

[b]A base of 200° F. was used.

[c]Pounds per square inch regulated pressure--miles per hour forward ground speed--no-hood (NH) or hood (H) flamers.

The temperature-time data collected from the curves of the eight treatments are presented in a more detailed form in Tables VII and VIII in the Appendix. The peak temperature recorded for this flamer operating under field conditions on the laboratory track was 1139°F. This temperature was recorded for the treatment, 80 pounds per square inch pressure and one mile per hour for the hooded flamer. The peak temperatures for this machine decreased to about 700°F. when the speed was increased to two miles per hour. The fuel consumption rate of the burners was reduced by 50 percent when the speed was increased from one to two miles per hour. The tremendous decline in temperature indicated the importance of operating any flamer at the recommended speed and gas pressure set forth by the manufacturer.

CHAPTER VI

SUMMARY AND CONCLUSIONS

An investigation was performed to determine the effectiveness of two types of alfalfa flaming units which were used for supplemental control of the alfalfa weevil. One flamer employed the use of an LP-gas tank, a hood with side shields, and two rows of thirteen A-130 AFCO burners. A centrifugal blower, powered by a Briggs and Stratton, three horsepower, gasoline engine was mounted on the hood to supply secondary air through six air ducts for more efficient combustion of the gases beneath the hood. This flamer was modified for the laboratory part of this study by removing the hood from the front row of burners. After this modification, the flamer proved more efficient; however, the efficiency was reduced considerably when the centrifugal blower was stopped.

The second flamer consisted merely of a LP-gas tank and two rows of A-130 AFCO burners. It had no hood but it had the identical burner arrangement as the first unit. This flamer was mounted on a three-point tractor hitch.

These two flamers were tested in the field for burning dormant alfalfa stubble. The treatments consisting of variable speeds and regulated gas pressures were conducted on plots 8 feet by 50 feet. The results of these experiments indicated no significant difference

between the treatment, 40 pounds per square inch pressure and two miles per hour speed for the non-hooded flamer as compared to the treatment, 50 pounds per square inch pressure and two miles per hour speed for a non-hooded flamer. However, there was a significant difference in some cases when the speed was increased from two to three miles per hour while maintaining the same regulated gas pressure.

These two flamers plus a commercial Manchester flamer with a convertible hover were used in a laboratory experiment which was done under field type conditions. The thermal analysis of these flamers was obtained from data collected from the flamers operating on an oval test track near The University of Tennessee Agricultural Engineering Building. A total of ten Chromel-Alumel thermocouples spaced six inches apart were buried on the track perpendicular to the direction of travel of the flamers.

A Honeywell 1508 Visicorder Oscillograph was used to obtain the temperature-time relationships for all thermocouples simultaneously as the flamer passed over them. The oscillograph recorded the output from the thermocouples which were directly below the burners on each flamer.

The laboratory tests indicated more than twice as much thermal energy was available beneath the burners of all the flamers when traveling at one mile per hour as compared to two miles per hour while the pressure remained the same. This showed a positive indication as to the importance of operating the flamers at the proper speed for a

recommended gas pressure. The change in gas pressure ratings was not as critical as the change in ground speed.

The temperature-time relationships recorded by the thermocouples showed there were hot and cool spots beneath the burners of all the flamers. The hooded flamers reflected this situation to a greater extent than the non-hooded flamers.

Based upon the results of the field and laboratory experiments, the following conclusions were made. Both of the hooded flamers had more available thermal energy than the non-hooded flamers while operating at the same speed and pressure ratio. However, for some treatments, there proved to be no significant difference in the statistical result of the above statement when analyzed at the 5 per cent level. This would mean that the advantages, which are cost, operational handling, and construction design, of using a non-hooded flamer could possibly outweigh the disadvantage of receiving a less effective control with this flamer.

The following areas are suggested for additional analysis and study:

1. Tests should be performed to determine the most efficient arrangement and spacing of the burners.

2. A detailed cost analysis could be performed on hooded and non-hooded flamers to determine if the advantages of using the non-hooded flamers outweigh the disadvantages of receiving a less effective control with them.

3. Further testing would develop an accurate method for regulating the volume of secondary air discharged beneath hooded flamers.

CRANESHOT CREST

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APPENDIX

TABLE V

TEMPERATURE-TIME DATA FOR ALFALFA FLAMER WITHOUT A HOOD[a]

Treatment	Thermocouple Number[b]	Area Under Curve[c] ($in.^2$)	Peak Temp. (°F)	Exposure Time in Seconds 800	600	400	200
40-1-NH[d]	1	10.7	951	0.7	2.5	8.5	12.0[e]
	2	7.9	796	0.1	2.0	5.5	12.0
	3	3.5	549	0	0	1.8	12.0
	4	5.8	678	0	0.5	3.6	12.0
	5	6.4	580	0	0	4.5	12.0
	6	5.0	715	0	1.1	3.6	12.0
	7	4.1	625	0	0.3	1.9	12.0
	8	5.2	704	0	0.6	3.1	12.0
	9	5.4	618	0	0.4	2.9	12.0
	10	2.6	468	0	0	1.0	9.3
50-1-NH	1	9.0	996	0.6	1.4	6.5	12.0
	2	8.8	828	0.3	2.6	5.9	12.0
	3	6.9	676	0	0.5	4.9	12.0
	4	6.9	729	0	0.8	4.7	12.0
	5	7.7	661	0	0.9	5.8	12.0
	6	6.0	741	0	1.0	3.8	12.0
	7	6.1	701	0	0.5	3.6	12.0
	8	8.0	769	0	1.0	6.6	12.0
	9	8.2	693	0	0.9	5.1	12.0
	10	4.8	528	0	0	2.5	12.0
60-1-NH	1	10.5	906	0.6	2.9	7.9	12.0
	2	7.9	744	0	2.0	5.1	12.0
	3	8.1	688	0	1.1	6.1	12.0
	4	8.9	724	0	1.4	6.8	12.0
	5	8.0	616	0	0.5	6.6	12.0
	6	7.9	788	0	1.2	4.7	12.0
	7	7.9	714	0	1.1	5.6	12.0
	8	10.9	849	0.5	2.3	9.1	12.0
	9	9.6	780	0	2.2	7.5	12.0
	10	5.8	583	0	0	3.5	12.0

TABLE V (CONTINUED)

Treatment	Thermocouple Number	Area Under Curve (in.^{2})	Peak Temp. (°F)	Exposure Time in Seconds 800	600	400	200
40-2-NH	1	3.6	695	0	0.5	1.9	11.0
	2	3.2	593	0	0	1.8	9.3
	3	1.2	404	0	0	0.3	5.6
	4	1.2	484	0	0	0.6	6.1
	5	2.0	459	0	0	0.8	9.7
	6	1.1	549	0	0	0.8	4.9
	7	0.8	421	0	0	0.3	4.0
	8	1.3	508	0	0	0.6	6.3
	9	1.6	480	0	0	1.2	6.6
	10	0.7	373	0	0	0	3.9
50-2-NH	1	2.6	633	0	0.3	1.6	8.9
	2	2.5	585	0	0	1.6	7.6
	3	1.2	409	0	0	0.4	5.8
	4	2.7	554	0	0	1.3	9.3
	5	2.2	448	0	0	0.7	8.8
	6	1.4	536	0	0	0.9	5.0
	7	0.9	463	0	0	0.4	5.0
	8	2.4	530	0	0	0.8	9.0
	9	2.7	573	0	0	1.3	10.0
	10	0.9	345	0	0	0	3.8
60-2-NH	1	4.8	776	0	1.0	2.6	11.5
	2	3.0	599	0	0	1.8	9.4
	3	2.8	519	0	0	1.4	9.9
	4	3.0	558	0	0	1.3	10.5
	5	3.4	493	0	0	1.6	11.4
	6	2.6	618	0	0.4	1.3	8.6
	7	2.7	573	0	0	1.1	10.2
	8	3.5	616	0	0.2	1.6	12.0
	9	4.0	601	0	0	1.9	12.0
	10	1.6	406	0	0	0.2	8.0

TABLE V (CONTINUED)

Treatment	Thermocouple Number	Area Under Curve ($in.^2$)	Peak Temp. (°F)	Exposure Time in Seconds 800	600	400	200
40-3-NH	1	1.5	568	0	0	1.0	5.9
	2	1.4	534	0	0	1.2	4.7
	3	0.2	278	0	0	0	1.3
	4	0.4	385	0	0	0	2.2
	5	0.6	356	0	0	0	4.3
	6	0.4	374	0	0	0	1.5
	7	0.2	335	0	0	0	0.9
	8	0.3	346	0	0	0	1.5
	9	0.6	461	0	0	0.3	2.7
	10	0.2	293	0	0	0	1.1
50-3-NH	1	1.1	581	0	0	0.8	3.9
	2	1.2	530	0	0	0.9	4.0
	3	0.2	321	0	0	0	1.2
	4	0.3	403	0	0	0.1	1.5
	5	0.4	350	0	0	0	2.6
	6	0.3	369	0	0	0	1.3
	7	0.2	373	0	0	0	1.0
	8	0.3	374	0	0	0	2.4
	9	0.7	464	0	0	0.4	3.1
	10	0.2	271	0	0	0	1.0
60-3-NH	1	1.8	601	0	0	1.2	6.0
	2	0.9	508	0	0	0.9	3.1
	3	0.6	384	0	0	0	3.0
	4	1.0	443	0	0	0.5	4.7
	5	0.7	386	0	0	0	4.2
	6	0.7	508	0	0	0.6	2.5
	7	0.5	419	0	0	0.2	2.0
	8	1.0	474	0	0	0.5	5.4
	9	1.1	496	0	0	0.7	4.3
	10	0.3	314	0	0	0	1.9

TABLE V (CONTINUED)

Treatment	Thermocouple Number	Area Under Curve (in.^{2})	Peak Temp. (°F)	Exposure Time in Seconds 800	600	400	200
40-4-NH	1	0.3	434	0	0	0.2	1.5
	2	0.7	494	0	0	0.6	2.4
	3	0	158	0	0	0	0
	4	0.1	271	0	0	0	0.5
	5	0.2	311	0	0	0	1.2
	6	0.2	303	0	0	0	1.0
	7	0.1	228	0	0	0	0.4
	8	0.1	221	0	0	0	0.3
	9	0.3	373	0	0	0	1.3
	10	0.1	248	0	0	0	0.5
50-4-NH	1	0.7	506	0	0	0.5	1.8
	2	0.6	439	0	0	0.4	1.7
	3	0.2	288	0	0	0	0.8
	4	0.2	339	0	0	0	1.1
	5	0.2	281	0	0	0	1.0
	6	0.1	303	0	0	0	0.7
	7	0.2	311	0	0	0	0.7
	8	0.2	334	0	0	0	1.1
	9	0.5	413	0	0	0.2	1.6
	10	0.1	246	0	0	0	0.6

TABLE V (CONTINUED)

Treatment	Thermocouple Number	Area Under Curve (in.^{2})	Peak Temp. (°F)	Exposure Time in Seconds 800	600	400	200
60-6-NH	1	0.9	565	0	0	0.6	3.0
	2	0.8	476	0	0	0.6	2.8
	3	0.2	331	0	0	0	1.5
	4	0.3	379	0	0	0	1.5
	5	0.2	315	0	0	0	1.3
	6	0.3	384	0	0	0	1.1
	7	0.2	356	0	0	0	0.9
	8	0.3	363	0	0	0	1.3
	9	0.6	448	0	0	0.4	2.3
	10	0.2	291	0	0	0	0.9

[a]Data were collected January 18, 1968, The University of Tennessee.

[b]Values for each thermocouple are average values for four replications.

[c]A base of 200° F. was used.

[d]Pounds per square inch regulated pressure--miles per hour forward ground speed--no hood (NH) flamer.

[e]A maximum time of 12 seconds was considered.

TABLE VI

TEMPERATURE-TIME DATA FOR ALFALFA FLAMER WITH A HOOD[a]

Treatment	Thermocouple Number[b]	Area Under Curve[c] (in.^{2})	Peak Temp. (°F)	Exposure Time in Seconds			
				800	600	400	200
40-1-H[d]	1	10.6	698	0	1.9	10.1	12.0[e]
	2	10.8	775	0	2.8	9.8	12.0
	3	5.6	477	0	0	4.4	12.0
	4	9.1	753	0	1.6	7.2	12.0
	5	6.7	558	0	0	5.7	12.0
	6	4.5	438	0	0	2.2	12.0
	7	5.8	798	0	0.6	4.0	12.0
	8	8.1	588	0	0	7.3	12.0
	9	9.7	650	0	1.6	8.7	12.0
	10	9.5	742	0	1.7	8.4	12.0
50-1-H	1	10.9	807	0.3	2.6	9.3	12.0
	2	10.4	800	0.2	2.4	8.9	12.0
	3	7.1	675	0	0.6	5.3	12.0
	4	4.9	753	0	0.8	3.5	11.5
	5	4.2	548	0	0	2.0	12.0
	6	4.2	583	0	0	1.9	11.5
	7	7.3	860	0.4	1.2	5.4	12.0
	8	9.2	640	0	1.1	7.7	12.0
	9	10.7	688	0	2.5	9.9	12.0
	10	3.0	453	0	0	1.3	8.8
60-1-H	1	16.2	872	1.1	7.8	12.0	12.0
	2	16.1	885	1.1	6.8	12.0	12.0
	3	13.5	713	0	5.0	11.0	12.0
	4	14.1	888	1.0	5.1	10.4	12.0
	5	10.8	642	0	3.6	9.4	12.0
	6	9.9	623	0	0.3	8.2	12.0
	7	12.1	927	0.5	4.5	9.5	12.0
	8	13.9	770	0	5.9	11.4	12.0
	9	14.5	762	0	5.9	11.8	12.0
	10	12.8	827	0.8	4.4	11.0	12.0

TABLE VI (CONTINUED)

Treatment	Thermocouple Number	Area Under Curve (in.^{2})	Peak Temp. (°F)	Exposure Time in Seconds 800	600	400	200
40-2-H	1	3.2	433	0	0	0.2	12.0
	2	3.9	473	0	0	1.3	12.0
	3	1.6	295	0	0	0	8.6
	4	3.2	570	0	0	1.1	10.0
	5	1.8	353	0	0	0	8.4
	6	1.2	327	0	0	0	6.6
	7	2.0	575	0	0	0.8	7.5
	8	2.3	385	0	0	0	8.8
	9	2.8	405	0	0	0.2	10.9
	10	2.7	422	0	0	0.4	9.7
50-2-H	1	5.1	597	0	0	2.8	12.0
	2	4.9	633	0	0.3	2.6	12.0
	3	3.1	500	0	0	1.2	10.2
	4	2.2	613	0	0.1	1.5	8.0
	5	1.8	435	0	0	0.3	7.5
	6	1.0	398	0	0	0	4.8
	7	2.2	638	0	0.1	1.3	7.5
	8	3.0	483	0	0	1.9	9.8
	9	3.7	470	0	0	1.3	11.8
	10	0.6	337	0	0	0	3.5
60-2-H	1	7.6	662	0	0.9	5.6	12.0
	2	8.1	703	0	1.6	6.2	12.0
	3	5.3	530	0	0	3.5	12.0
	4	4.4	630	0	0.3	3.2	10.8
	5	3.6	447	0	0	1.5	11.0
	6	3.8	500	0	0	1.9	10.9
	7	3.8	672	0	0.4	2.8	10.0
	8	4.9	510	0	0	3.3	12.0
	9	5.2	492	0	0	3.3	12.0
	10	4.2	578	0	0	2.5	12.0

TABLE VI (CONTINUED)

Treatment	Thermocouple Number	Area Under Curve (in.^{2})	Peak Temp. (°F)	Exposure Time in Seconds 800	600	400	200
40-3-H	1	1.5	398	0	0	0	7.6
	2	1.4	390	0	0	0	6.5
	3	0.4	257	0	0	0	2.8
	4	0.8	375	0	0	0	3.5
	5	0.9	365	0	0	0	4.8
	6	0.3	297	0	0	0	2.7
	7	0.6	462	0	0	0.2	2.4
	8	0.7	328	0	0	0	3.7
	9	0.5	287	0	0	0	3.4
	10	1.0	393	0	0	0	5.4
50-3-H	1	2.7	490	0	0	1.2	9.4
	2	2.6	532	0	0	1.1	9.0
	3	1.0	335	0	0	0	5.5
	4	1.7	528	0	0	1.1	5.5
	5	0.6	3 5	0	0	0	4.1
	6	0.8	368	0	0	0	4.0
	7	1.2	527	0	0	0.6	3.8
	8	1.2	388	0	0	0	5.2
	9	1.5	393	0	0	0	6.7
	10	1.2	470	0	0	0.6	4.8
60-3-H	1	4.0	547	0	0	2.1	12.0
	2	4.4	573	0	0	2.3	12.0
	3	2.9	413	0	0	0.2	10.9
	4	3.2	577	0	0	2.1	9.8
	5	1.8	402	0	0	0.1	7.8
	6	1.2	377	0	0	0	6.7
	7	1.5	570	0	0	0.6	6.9
	8	2.5	423	0	0	0.2	9.4
	9	2.6	402	0	0	0.3	9.1
	10	2.7	543	0	0	1.7	10.8

TABLE VI (CONTINUED)

Treatment	Thermocouple Number	Area Under Curve (in.^{2})	Peak Temp. (°F)	Exposure Time in Seconds 800	600	400	200
40-4-H	1	0.5	320	0	0	0	3.0
	2	0.7	387	0	0	0	3.7
	3	0.1	212	0	0	0	0.6
	4	0.6	390	0	0	0	2.2
	5	0.2	275	0	0	0	0.9
	6	0.1	217	0	0	0	0.5
	7	0.3	358	0	0	0	1.3
	8	0.1	245	0	0	0	1.0
	9	0.1	225	0	0	0	0.7
	10	0.3	308	0	0	0	1.5
50-4-H	1	1.4	427	0	0	0.2	6.4
	2	1.4	465	0	0	0.5	6.6
	3	0.5	287	0	0	0	2.9
	4	1.0	490	0	0	0.5	3.5
	5	0.2	273	0	0	0	1.6
	6	1.2	340	0	0	0	5.5
	7	0.5	455	0	0	0.3	1.6
	8	0.5	347	0	0	0	2.8
	9	0.4	327	0	0	0	3.1
	10	0.3	312	0	0	0	1.5
60-4-H	1	1.9	445	0	0	0.3	7.0
	2	1.9	443	0	0	0.4	7.0
	3	0.6	275	0	0	0	3.6
	4	1.2	452	0	0	0.5	3.9
	5	0.6	303	0	0	0	2.8
	6	0.5	288	0	0	0	2.6
	7	0.7	492	0	0	0.4	2.2
	8	0.7	320	0	0	0	3.2
	9	0.5	287	0	0	0	3.1
	10	0.7	355	0	0	0	2.9

[a]Data were collected February 2, 1968, The University of Tennessee Agriculture Campus.

[b]Values for each thermocouple are average values for three replications.

[c]A base of 200° F was used.

[d]Pounds per square inch regulated pressure--miles per hour forward ground speed--hood (H) flamer.

[e]A maximum time of 12 seconds was considered.

TABLE VII

TEMPERATURE-TIME DATA FOR MANCHESTER ALFALFA FLAMER WITH HOOD DOWN[a]

Treatment	Thermocouple Number[b]	Area Under Curve[c] (in.^{2})	Peak Temp. (°F)	Exposure Time in Seconds 800	600	400	200
80-1-H[d]	1	6.4	546	0	0	4.6	12.0[e]
	2	16.8	998	3.2	6.3	12.0	12.0
	3	18.1	953	3.7	7.8	12.0	12.0
	4	21.6	1139	5.2	9.3	12.0	12.0
	5	19.5	1028	4.7	9.0	12.0	12.0
	6	9.6	644	0	1.8	7.9	12.0
	7	6.0	569	0	0	4.2	12.0
	8	14.6	873	1.6	4.7	12.0	12.0
	9	15.1	860	1.6	5.9	12.0	12.0
80-2-H	1	4.9	569	0	0	3.1	12.0
	2	8.5	793	0	2.1	5.9	12.0
	3	6.4	585	0	0	4.5	12.0
	4	9.2	813	0.3	2.5	6.6	12.0
	5	4.2	513	0	0	2.6	12.0
	6	0.5	289	0	0	0	3.1
	7	2.0	533	0	0	1.4	6.0
	8	6.5	695	0	1.0	3.5	12.0
	9	5.3	596	0	0	3.1	12.0
80-3-H	1	0.7	406	0	0	0.1	3.1
	2	3.3	665	0	0.5	1.8	9.7
	3	2.5	443	0	0	1.2	8.3
	4	6.0	720	0	1.4	3.8	12.0
	5	4.2	535	0	0	2.4	11.6
	6	0.5	295	0	0	0	2.7
	7	1.0	453	0	0	0.5	3.1
	8	2.7	586	0	0	1.6	9.7
	9	2.1	460	0	0	0.9	8.2

TABLE VII (CONTINUED)

Treatment	Thermocouple Number	Area Under Curve ($in.^2$)	Peak Temp. (°F)	Exposure Time in Seconds 800	600	400	200
80-4-H	1	0.5	370	0	0	0	2.8
	2	2.3	579	0	0	1.4	8.4
	3	2.0	428	0	0	0.4	7.4
	4	3.4	638	0	0.4	1.9	10.3
	5	1.4	423	0	0	0.4	6.8
	6	0.1	230	0	0	0	0.6
	7	0.6	429	0	0	0.3	1.9
	8	1.0	488	0	0	0.6	4.4
	9	0.5	375	0	0	0	3.2

[a]Data were collected January 27, 1968, The University of Tennessee Agriculture Campus.

[b]Values for each thermocouple are average calues for four replications.

[c]A base of 200° F. was used.

[d]Pounds per square inch regulated pressure--miles per hour forward ground speed--hood (H) flamer.

[e]A maximum time of 12 seconds was considered.

TABLE VIII

TEMPERATURE-TIME DATA FOR MANCHESTER ALFALFA FLAMER WITH HOOD UP[a]

Treatment	Thermocouple Number[b]	Area Under Curve[c] (in.^{2})	Peak Temp. (°F)	Exposure Time in Seconds			
				800	600	400	200
80-1-NH[d]	1	7.9	564	0	0	6.7	12.0[e]
	2	13.6	793	0	5.3	10.0	12.0
	3	16.5	871	2.5	6.9	12.0	12.0
	4	17.9	1013	4.2	7.0	12.0	12.0
	5	13.7	814	2.2	5.1	9.0	12.0
	6	6.9	555	0	0	4.8	12.0
	7	4.9	558	0	0	3.2	8.9
	8	10.5	764	0	2.9	8.0	12.0
	9	11.8	780	0	4.3	9.7	12.0
80-2-NH	1	4.1	554	0	0	2.4	10.8
	2	7.6	776	0	1.4	4.8	12.0
	3	4.7	478	0	0	2.6	12.0
	4	6.9	698	0	1.3	4.4	12.0
	5	3.4	448	0	0	1.6	9.9
	6	3.0	460	0	0	1.4	8.8
	7	3.4	638	0	0.4	2.7	8.8
	8	4.4	591	0	0	2.7	10.7
	9	3.5	494	0	0	2.1	10.0
80-3-NH	1	2.6	530	0	0	1.3	9.3
	2	4.1	655	0	0.4	2.1	12.0
	3	1.8	371	0	0	0	8.4
	4	2.9	535	0	0	1.6	9.7
	5	0.6	318	0	0	0	4.1
	6	1.3	380	0	0	0	6.4
	7	1.3	483	0	0	1.1	4.7
	8	1.4	441	0	0	0.8	5.1
	9	1.3	380	0	0	0	5.2

TABLE VIII (CONTINUED

Treatment	Thermocouple Number	Area Under Curve ($in.^2$)	Peak Temp. (°F)	Exposure Time in Seconds 800	600	400	200
80-4-NH	1	0.9	479	0	0	0.4	4.0
	2	1.9	618	0	0.2	1.1	6.8
	3	1.1	409	0	0	0.3	5.5
	4	2.0	555	0	0	1.2	6.7
	5	0.9	359	0	0	0	4.0
	6	0.7	441	0	0	0.3	3.3
	7	0.9	493	0	0	0.7	2.5
	8	0.8	439	0	0	0.4	3.1
	9	0.8	408	0	0	0.2	3.2

[a]Data were collected January 27, 1968, The University of Tennessee Agriculture Campus.

[b]Values for each thermocouple are average values for four replications.

[c]A base of 200° F. was used.

[d]Pounds per square inch regulated pressure--miles per hour forward ground speed--no-hood (NH) flamer.

[e]A maximum time of 12 seconds was considered.